OLIGOCENE AND LOWER MIOCENE.*

LIST OF SPECIES	9	10	12	13	24	25	29	43	44	45	53	54	56
PELECYPODA													
1 Acila shumardi Dall	*	...	...		...	...	...	*	...	...	...	...	...
2 Acila gettysburgensis Reagan	*	...	...	...	...	...	...	...	...	...	...	...	...
3 Acila conradi Meek	...	...	...	...	...	...	...	...	...	...	...	*	*
4 Anomia subcostata Conrad	...	...	...	...	...	...	...	...	...	...	...	...	...
5 Arca trilineata Conrad	...	...	...	...	...	...	...	...	...	...	*	*	...
6 Arca montereyana Osmont	...	...	...	...	...	...	...	...	...	...	*	*	...
7 Cardium lorenzanum (Arnold)	...	*	...	...	...	...	...	...	...	...	...	...	...
8 Cardium coosensis Dall	...	...	...	...	...	...	...	...	...	...	...	...	...
9 Cardium lincolnensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
10 Cardium vaqueroensis Arnold	...	...	...	...	...	...	...	...	...	...	...	...	...
11 Chione securis (Shumard)	...	...	...	...	...	...	...	...	...	...	...	*	...
12 Chione clallamensis Reagan	...	...	...	...	...	...	...	...	...	...	...	...	...
13 Chione olympidea Reagan	...	...	...	...	...	...	...	...	...	...	...	...	...
14 Chione cathcartensis Weaver	...	...	*	*	...	...	...	...	...	...	...	...	...
15 Chione temblorensis Anderson	...	...	...	...	...	...	...	...	...	...	...	...	...
16 Callocallista arnoldi Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
17 Crenella porterensis Weaver	...	...	...	*	...	...	...	...	...	...	...	...	...
18 Crassatellites washingtonensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
19 Crassatellites cowlitzensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
20 Crassatellites lincolnensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
21 Crenella washingtonensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
22 Glycimeris chehalisensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
23 Leda washingtonensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
24 Leda lincolnensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
25 Leda chehalisensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
26 Leda oschsneri Anderson	...	...	...	...	...	...	...	...	...	...	...	...	...
27 Macrocallista pittsburgensis Dall	...	...	...	...	...	...	...	...	...	...	...	...	...
28 Macrocallista vespertina Conrad	...	...	*	*	...	...	...	...	...	...	...	...	...
29 Marcia oregonensis (Conrad)	...	*	*	*	...	...	...	...	...	*	...	...	...
30 Macoma secta Conrad	...	...	...	...	...	...	...	...	...	...	...	...	...
31 Macoma nasuta Conrad	...	...	...	...	...	...	...	...	...	...	...	...	...
32 Macoma calcaria Gmelin	...	*	...	...	...	...	...	...	...	...	...	...	...
33 Macoma clallamensis Reagan	...	...	...	...	...	...	...	...	...	...	...	...	...
34 Macoma wynoocheensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
35 Modiolus directus Dall	...	*	...	...	...	...	...	...	...	...	...	...	...
36 Modiolus inflatus Dall	...	...	...	...	...	...	...	...	...	...	...	...	...
37 Malletia chehalisensis Arnold	...	...	...	...	...	...	...	*	...	...	...	...	...
38 Mytilus mathewsoni Gabb	...	...	...	...	...	...	...	...	...	...	...	...	...
39 Mytilus sammamishensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
40 Mytilus snohomishensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
41 Nucula washingtonensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
42 Ostraea veatchii Gabb	...	...	...	...	...	...	...	...	...	...	...	...	...
43 Ostraea lincolnensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
44 Ostraea idraensis Gabb	...	...	...	...	...	...	...	...	...	...	...	...	...
45 Panope generosa (Gould)	...	...	*	...	...	...	...	...	...	...	...	...	...
46 Pandora washingtonensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
47 Pitaria dalli Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
48 Pecten propatulus Conrad	...	...	...	...	...	*	...	...	...	...	...	*	...
49 Pecten fucanus Arnold	...	...	...	...	...	...	...	...	...	...	...	...	...
50 Pecten peckhami Gabb	...	...	...	...	...	...	...	...	*	...	...	...	...
51 Pecten porterensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
52 Pecten alockamanensis Weaver	...	...	...	...	...	...	...	...	...	...	*	*	...
53 Phacoides acutilineatus (Conrad)	...	*	*	*	*	*	*	...	...	...	...	*	...
54 Phacoides annulatus Reeves	...	...	...	...	...	...	...	...	...	...	...	...	...
55 Solemya ventricostata Conrad	...	...	*	...	...	...	*	...	...	...	...	...	...
56 Solen curtus Conrad	...	...	...	...	...	...	...	*	...	...	...	...	...
57 Solen lincolnensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
58 Solen parallelus Gabb	...	...	...	...	...	...	...	...	...	...	...	...	...
59 Spisula albaria (Conrad)	...	...	...	*	...	...	...	...	...	...	...	*	*
60 Spisula catilliformis Conrad	...	...	...	...	...	...	...	...	...	...	...	...	...
61 Tapes staleyi Gabb	...	...	...	...	...	...	...	...	...	...	*	...	...
62 Tellina obruta Conrad	...	...	...	...	...	...	...	...	...	...	...	*	*
63 Tellina lincolnensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...
64 Tellina oregonensis Conrad	...	...	...	...	...	...	...	...	...	...	...	...	...
65 Tellina arctata Conrad	...	...	...	...	...	...	...	...	...	...	...	...	...
66 Tellina conjesta Conrad	...	...	...	...	...	...	...	...	...	...	...	...	...
67 Tellina nuculana Dall	*	...	*	...	...	...	...	...	...	...	...	...	...
68 Tellina nevadensis Anderson	...	...	...	...	...	...	...	...	...	...	...	...	...
69 Thracia trapezoidea Conrad	...	...	*	*	...	...	...	...	...	...	...	...	...
70 Thracia oregonensis Dall	...	...	...	...	...	...	...	...	...	...	...	...	...
71 Thyasira bisecta (Conrad)	...	*	*	...	...	*	...	...	...	...	...	...	...
72 Venericardia subtenta (Conrad)	*	...	*	...	...	...	...	...	...	...	...	...	...
73 Venericardia chehalisensis Weaver	...	...	...	...	...	...	...	...	*	...	...	...	...
74 Yoldia oregona Shumard	...	...	...	...	...	...	...	...	...	...	...	...	...
75 Yoldia impressa Conrad	*	*	*	...	...	...	...	...	...	...	...	...	...
76 Yoldia submontereyensis Arnold	...	...	...	...	...	...	...	...	...	...	*	*	...
77 Yoldia sammamishensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...	...

* From Tertiary Faunal Horizons of Western Washington, University of Washington Publications in Geology, Vol. I, No. 1, pp. 28-31.

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OLIGOCENE AND LOWER MIOCENE—Continued.

	57	59	63	65	66	67	70	71	73	74	77	80	81	88	90	92	97	98	102	103	105	106	107	108	109
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OLIGOCENE AND LOWER MIOCENE—Continued.

	LIST OF SPECIES	9	10	12	13	24	25	29	43	44	45	53	54	56
	SCAPHAPODA													
78	Dentalium stramineum Gabb													
79	Dentalium conradi Dall		*	*	*		*						*	*
80	Dentalium porterensis Weaver													
	GASTEROPODA													
81	Acteocina chehalisensis Weaver													
82	Ampullina oregonensis Dall													
83	Brachysphingus clarki Weaver													
84	Bittium lincolnensis Weaver													
85	Calyptraea excentrica (Gabb)													
86	Calyptraea washingtonensis Weaver													
87	Calyptraea filosa (Gabb)											*	*	
88	Calyptraea inornata (Gabb)													
89	Cancellaria wynootcheensis Weaver													
90	Cancellaria washingtonensis Weaver													
91	Cancellaria condoni Anderson											*	*	
92	Cancellaria dalliana Anderson											*	*	
93	Chrysodomus washingtonensis Weaver													
94	Chrysodomus packardi Weaver													
95	Chrysodomus clallamensis Weaver													
96	Crepidula princeps Conrad												*	
97	Crepidula praerupta Conrad											*	*	
98	Calliostoma delazinensis Weaver								*					
99	Chlorastoma arnoldi Weaver								*					
100	Drillia chehalisensis (Arnold)								*					
101	Cylichnella petrosa Conrad								*					
102	Epitonium washingtonensis Weaver													
103	Epitonium condoni Dall													
104	Epitonium rugiferum Dall													
105	Exilia lincolnensis Weaver													
106	Exilia dickersoni Weaver													
107	Eudolium petrosum (Conrad)	*	*		*						*			
108	Fusinus stanfordensis (Arnold)												*	
109	Fusinus corpulentus (Conrad)													
110	Ficus wynootcheensis Weaver													
111	Ficus chehalisensis Weaver													
112	Ficus oregonensis Conrad													
113	Ficus clallamensis Weaver													
114	Hemifusus washingtonensis Weaver													
115	Molopophorous gabbi Dall													
116	Molopophorous biplicata (Gabb)													
117	Molopophorous lincolnensis Weaver													
118	Miopleiona indurata Conrad													
119	Mesalia lincolnensis Weaver													
120	Nassa chehalisensis Weaver													
121	Nassa andersoni Weaver													
122	Nassa arnoldi Anderson													
123	Natica oregonensis Conrad	*			*						*	*	*	*
124	Natica washingtonensis Weaver													
125	Natica lincolnensis Weaver													
126	Natica lewisii (Gould)													
127	Natica olympidii Reagan													
128	Natica saxea Conrad													
129	Olivella pedroana Conrad													
130	Phalium aequisulcatum Dall													
131	Pisania clallamensis Weaver													
132	Scaphander washingtonensis Weaver													
133	Scaphander oregonensis Dall													
134	Strepsidura oregonensis Dall													
135	Strepsidura californica Arnold													
136	Sinum scopulosum Conrad													
137	Turris perissolaxoides Arnold													
138	Turris thurstonensis Weaver													
139	Turris packardi Weaver													
140	Turris dickersoni Weaver													
141	Turris kincaidi Weaver													
142	Turris clallamensis Weaver													
143	Turris wynoocheensis Weaver													
144	Turcicula washingtonensis Dall	*	*		*									
145	Turritella oregonensis Conrad													
146	Turritella porterensis Weaver													
147	Turritella blakeleyensis Weaver				*									
148	Turritella newcombei Merriam	*	*	*										
149	Brachyuran remains													
150	Aturia angustata Conrad		*										*	
151	Foraminifera sp.													
152	Sharks teeth													
153	Hemithyris astoriana Dall													
154	Terebratula oakvillensis Weaver	*		*										
155	Terebratalia occidentalis Dall	*		*										

OLIGOCENE AND LOWER MIOCENE—CONTINUED.

	57	59	63	65	66	67	70	71	73	74	77	80	81	88	90	92	97	98	102	103	105	106	107	108	109
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OLIGOCENE AND LOWER MIOCENE—Continued.

LIST OF SPECIES	128	129	130	145	155	156	157	158	159	164	165	167
PELECYPODA												
1 Acila shumardi Dall				*	*				*			
2 Acila gettysburgensis Reagan												
3 Acila conradi Meek												*
4 Anomia subcostata Conrad												
5 Arca trilineata Conrad				*								
6 Arca montereyana Osmont												
7 Cardium lorenzanum (Arnold)											*	
8 Cardium coosensis Dall												
9 Cardium lincolnensis Weaver												
10 Cardium vaqueroensis Arnold												
11 Chione securis (Shumard)												
12 Chione clallamensis Reagan												
13 Chione olympidea Reagan												
14 Chione cathcartensis Weaver					*	*	*			*		
15 Chione temblorensis Anderson												
16 Callocallista arnoldi Weaver												
17 Crenella porterensis Weaver				*						*		
18 Crassatellites washingtonensis Weaver												
19 Crassatellites cowlitzensis Weaver												
20 Crassatellites lincolnensis Weaver												
21 Crenella washingtonensis Weaver												
22 Glycimeris chehalisensis Weaver												
23 Leda washingtonensis Weaver												
24 Leda lincolnensis Weaver												
25 Leda chehalisensis Weaver												
26 Leda oschsneri Anderson												
27 Macrocallista pittsburgensis Dall												
28 Macrocallista vespertina Conrad					*	*	*			*		
29 Marcia oregonensis (Conrad)					*				*			
30 Macoma secta Conrad												
31 Macoma nasuta Conrad												
32 Macoma calcaria Gmelin					*							*
33 Macoma clallamensis Reagan												
34 Macoma wynoocheensis Weaver												
35 Modiolus directus Dall				*								
36 Modiolus inflatus Dall				*								
37 Malletia chehalisensis Arnold									*			
38 Mytilus mathewsoni Gabb												
39 Mytilus sammamishensis Weaver							*					
40 Mytilus snohomishensis Weaver		*										
41 Nucula washingtonensis Weaver												
42 Ostraea veatchii Gabb												
43 Ostraea lincolensis Weaver												
44 Ostraea idraensis Gabb												
45 Panope generosa (Gould)					*	*	*					
46 Pandora washingtonensis Weaver												
47 Pitaria dalli Weaver												
48 Pecten propatulus Conrad												
49 Pecten fucanus Arnold												
50 Pecten peckhami Gabb												
51 Pecten porterensis Weaver												
52 Pecten alockamanensis Weaver												
53 Phacoides acutilineatus (Conrad)				*						*		
54 Phacoides annulatus Reeves												
55 Solemya ventricostata Conrad				*								
56 Solen curtus Conrad				*		*	*	*				*
57 Solen lincolnensis Weaver												
58 Solen parallelus Gabb												
59 Spisula albaria (Conrad)						*						
60 Spisula catilliformis Conrad												
61 Tapes staleyi Gabb												
62 Tellina obruta Conrad												
63 Tellina lincolnensis Weaver												
64 Tellina oregonensis Conrad					*	*	*	*			*	*
65 Tellina aretata Conrad												
66 Tellina conjesta Conrad												
67 Tellina nuculana Dall												
68 Tellina nevadensis Anderson												
69 Thracia trapezoidea Conrad	*			*						*		
70 Thracia oregonensis Dall												
71 Thyasira bisecta (Conrad)										*		
72 Venericardia subtenta (Conrad)												
73 Venericardia chehalisensis Weaver												
74 Yoldia oregona Shumard												
75 Yoldia impressa Conrad												
76 Yoldia submontereyensis Arnold												
77 Yoldia sammamishensis Weaver		*										

OLIGOCENE AND LOWER MIOCENE—CONTINUED.

	168	169	171	172	172	178	179	187	188	192	207	228	229	230	257	258	259	260	261	269	270	271	272	273	280
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OLIGOCENE AND LOWER MIOCENE—CONTINUED.

	LIST OF SPECIES	128	129	130	145	155	156	157	158	159	164	165	167
	SCAPHAPODA												
78	Dentalium stramineum Gabb	...	...	...	...	...	...	...	...	...	...	...	...
79	Dentalium conradi Dall	...	...	...	...	*	...	...	...	...	*	*	*
80	Dentalium porterensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
	GASTEROPODA												
81	Acteocina chehalisensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
82	Ampullina oregonensis Dall	...	...	...	...	...	...	...	...	...	...	...	...
83	Brachysphingus clarki Weaver	...	...	...	...	...	...	...	...	...	...	...	...
84	Bittium lincolnensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
85	Calyptraea excentrica (Gabb)	...	...	...	...	...	...	...	...	...	...	...	...
86	Calyptraea washingtonensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
87	Calyptraea filosa (Gabb)	...	...	...	...	...	...	...	...	...	...	...	...
88	Calyptraea inornata (Gabb)	...	...	...	...	...	...	...	...	*	...	...	...
89	Cancellaria wynootcheensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
90	Cancellaria washingtonensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
91	Cancellaria condoni Anderson	...	...	...	...	...	...	...	...	...	...	...	...
92	Cancellaria dalliana Anderson	...	...	...	...	...	...	...	...	...	...	...	...
93	Chrysodomus washingtonensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
94	Chrysodomus packardi Weaver	...	...	...	...	...	...	...	...	...	...	...	...
95	Chrysodomus clallamensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
96	Crepidula princeps Conrad	...	...	...	...	*	*	...	...	*	...	...	...
97	Crepidula praerupta Conrad	...	...	...	...	...	...	...	...	...	...	...	...
98	Calliostoma delazinensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
99	Chlorastoma arnoldi Weaver	...	...	...	...	...	...	...	...	...	...	...	...
100	Drillia chehalisensis (Arnold)	...	...	...	...	...	...	...	...	...	...	...	...
101	Cylichnella petrosa Conrad	...	...	...	...	...	...	...	...	...	...	...	...
102	Epitonium washingtonensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
103	Epitonium condoni Dall	...	...	...	...	...	...	...	...	*	...	*	...
104	Epitonium rugiferum Dall	...	...	...	...	...	...	...	...	*	...	...	...
105	Exilia lincolnensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
106	Exilia dickersoni Weaver	...	...	...	...	...	...	...	...	...	...	...	...
107	Eudolium petrosum (Conrad)	...	...	*	...	...	...	...	...	*	*	...	...
108	Fusinus stanfordensis (Arnold)	...	...	...	...	...	...	...	...	*	...	...	...
109	Fusinus corpulentus (Conrad)	...	...	...	...	...	...	...	...	...	...	...	...
110	Ficus wynootcheensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
111	Ficus chehalisensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
112	Ficus oregonensis Conrad	...	...	...	...	...	...	...	...	...	...	...	...
113	Ficus clallamensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
114	Hemifusus washingtonensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
115	Molopophorous gabbi Dall	...	...	...	...	...	...	...	...	*	...	...	...
116	Molopophorous biplicata (Gabb)	...	...	...	...	...	...	...	...	...	...	...	...
117	Molopophorous lincolnensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
118	Miopleiona indurata Conrad	...	...	...	...	...	...	...	...	...	*	...	...
119	Mesalia lincolnensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
120	Nassa chehalisensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
121	Nassa andersoni Weaver	...	...	...	...	...	...	...	...	...	...	...	...
122	Nassa arnoldi Anderson	...	...	...	...	...	...	...	...	...	...	...	...
123	Natica oregonensis Conrad	...	...	...	*	*	*	...	...	*	*	*	...
124	Natica washingtonensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
125	Natica lincolnensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
126	Natica lewisii (Gould)	...	...	...	...	...	...	...	...	...	...	...	...
127	Natica olympidii Reagan	...	...	...	...	...	...	...	...	...	...	...	...
128	Natica saxea Conrad	...	...	...	...	...	...	...	...	...	...	...	...
129	Olivella pedroana Conrad	...	...	...	...	...	...	...	...	...	...	...	...
130	Phalium aequisulcatum Dall	...	...	...	...	...	...	...	...	...	...	...	...
131	Pisania clallamensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
132	Scaphander washingtonensis Weaver	...	...	...	...	...	...	...	...	...	*	*	*
133	Scaphander oregonensis Dall	...	...	...	...	...	...	...	...	...	...	...	...
134	Strepsidura oregonensis Dall	...	...	...	...	...	...	...	...	*	...	...	*
135	Strepsidura californica Arnold	...	...	...	...	...	...	...	...	...	...	...	...
136	Sinum scopulosum Conrad	...	...	...	...	...	...	...	...	...	...	...	...
137	Turris perissolaxoides Arnold	...	...	...	...	...	...	...	...	...	...	...	...
138	Turris thurstonensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
139	Turris packardi Weaver	...	...	...	...	...	...	...	...	...	...	...	...
140	Turris dickersoni Weaver	...	...	...	...	...	...	...	...	...	...	...	...
141	Turris kincaidi Weaver	...	...	...	...	...	...	...	...	...	...	...	...
142	Turris clallamensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
143	Turris wynoocheensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
144	Turricula washingtonensis Dall	...	...	...	*	...	...	...	...	...	*	...	...
145	Turritella oregonensis Conrad	...	...	...	...	...	...	...	...	...	...	...	...
146	Turritella porterensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
147	Turritella blakeleyensis Weaver	...	...	...	*	...	...	...	...	...	*	...	...
148	Turritella newcombei Merriam	...	...	...	...	...	...	...	...	...	...	...	...
149	Brachyuran remains	...	...	...	...	...	...	...	...	...	...	...	...
150	Aturia angustata Conrad	...	...	...	*	...	...	...	...	...	*	...	...
151	Foraminfera sp.	...	...	...	...	...	...	...	...	...	...	...	...
152	Sharks teeth	...	...	...	...	...	...	...	...	...	...	...	...
153	Hemithyris astoriana Dall	...	...	...	...	...	...	...	...	...	...	...	...
154	Terebratula oakvillensis Weaver	...	...	...	...	...	...	...	...	...	...	...	...
155	Terebratalia occidentalis Dall	...	...	...	...	...	...	...	...	...	...	...	...

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OLIGOCENE AND LOWER MIOCENE—Concluded.

	168	169	171	172	172	178	179	187	188	192	207	228	229	230	257	258	259	260	261	269	270	271	272	273	280
78	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	*
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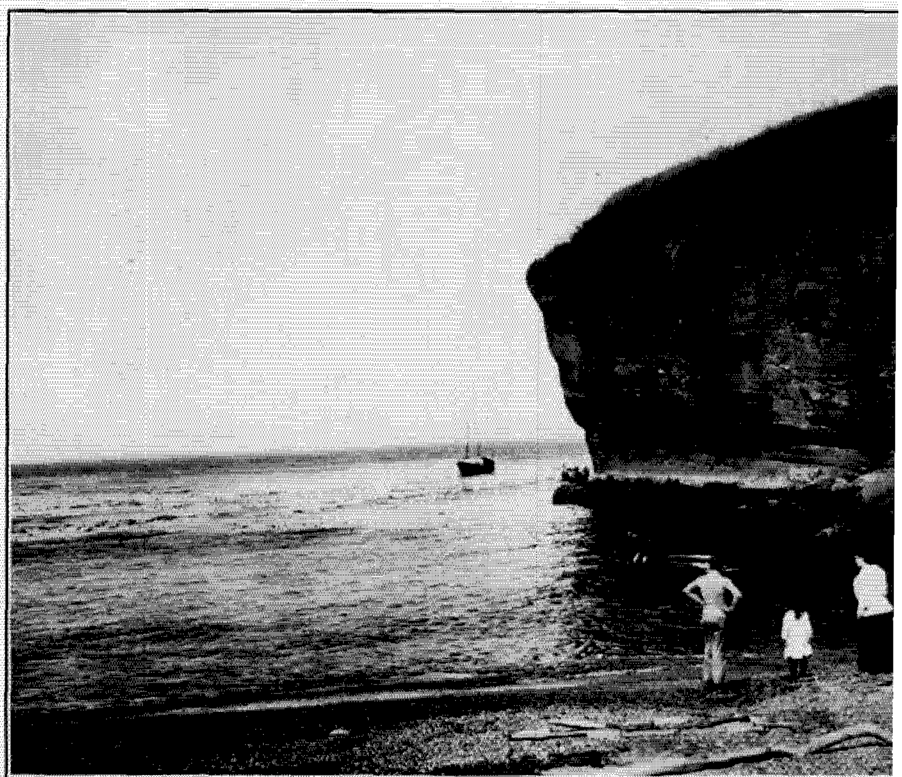

Oligocene Sandstone Exposed at the Boat Landing on '

DNR-00005167

LITHOLOGY.

The rock materials composing the Oligocene of western Washington are almost entirely of marine sedimentary origin. Interbedded lavas and tuffs are absent except on the north side of Columbia River in Pacific County. The sedimentary rocks consist of shales and sandy shales together with minor amounts of sandstones and conglomerates. A microscopic examination of these materials shows them to be in part derived from older igneous rocks. A considerable quantity of ash is present but always mixed with clayey material. The source of the tuffaceous materials was presumably from volcanic sources in the Cascades or eastern Washington. In northern Wahkiakum County andesitic flows were being deposited in marine embayments near the shore. Evidence for this is to be found in the sections exposed along the canyon of Nasel River.

The conglomerates occurring within the Oligocene of Seattle and at the entrance to the Bremerton Navy Yard are made up of pebbles ranging from the size of a pea to a foot or more in diameter. They are rounded and waterworn and composed in part of andesite and basalt and in part of sandstones and shales occurring within the formation. Pebbles made of quartzite and granite or diorite are very rare.

At the western end of Cape Flattery there are enormous belts of conglomerate in which the boulders are often over four feet in diameter. Commonly they are angular and only partially waterworn. They are in part composed of rocks which are not known to occur within the Olympic Peninsula but which do occur on Vancouver Island. The most common are quartzite, slate, schist and intrusive diorites and gabbros.

STRATIGRAPHY.

The more detailed facts concerning the stratigraphy are given in the description of the different districts in which the Oligocene deposits occur. It is not always possible to deter-

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mine in the different sections just where the boundaries should be drawn between the three faunal zones or horizons.

In the vicinity of Lincoln Creek, west of Centralia, massive sandy shales outcrop along the south bank of Chehalis River. Very good exposures have been made in the cuts of the O.-W. R. R. & N. Co. The beds are dipping at a very low angle to the west and southwest. Interbedded with the sandy shales are narrow bands of clay shale. Often the sandy shales grade into a shaly sandstone. To the north of Chehalis River Eocene sandstones outcrop at Grand Mound. The Oligocene beds at Lincoln Creek rest upon the Eocene sandstones but the contact relations are obscure. Presumably they are unconformable. The total thickness of the lower Oligocene strata in the Lincoln Creek section is near 1,000 feet.

In the region where Porter Creek joins Chehalis River, near the town of Porter, the total thickness of the Oligocene sediments is about 2,000 feet. The section represents the shales and shaly sandstones exposed from the base of the section three miles north of Porter to the center of the syncline three miles west of Porter. These strata contain a fauna which has been designated as the Turritella porterensis Zone. It is possible that the lower 500 feet of the section may belong to the Lincoln Horizon or Molopophorous lincolnensis Zone.

In the Puget Sound region a section has been constructed at the entrance to the Bremerton Navy Yard. The district involved may be referred to on Plate XXIV. The strata are entirely of sedimentary origin. The Eocene basalts upon which the Oligocene sediments rest are exposed two miles southwest of Bremerton, on the west shore of Sinclair Inlet. The contact between the basalt and the base of the Oligocene is covered with deposits of glacial drift. The lowermost beds occur at Orchard Point. The upper beds outcrop on the north side of Blakeley Harbor. The total measured thickness of the Oligocene in this section is approximately 8,900 feet.

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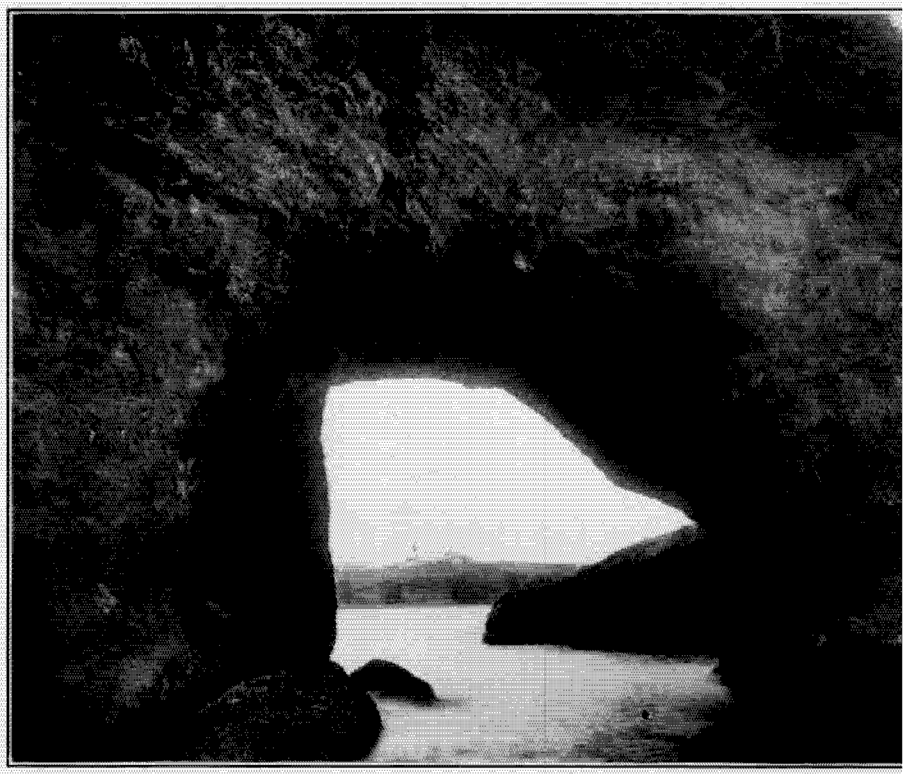


Oligocene Sandstone Exposed on the North Shores of Cape Flattery. Tat

Top of Section.	*Feet.*
(A) Massive coarse grained conglomeratic standstones, containing numerous lenticular bands of conglomerate. Occasional narrow bands of clay shale are interbedded. The eastward continuation of the conglomerates appear in the outcrops at Blakeley Rock. The beds persistently dip to the north at a very steep angle and extend as outcrops from the north shore of Blakeley Harbor northward for 1,500 feet	1300
(B) Sandy shales exposed beneath the waters of Blakeley Harbor	1400
(C) Brownish gray massive to slightly bedded shales as exposed along the south shore of Blakeley Harbor for a distance of one-half mile northwesterly. Five hundred feet stratigraphically above the beds exposed at Restoration Point is an excellent fossil locality	2400
(D) Shaly sandstones grading in places into a sandy shale. Bedding planes sometimes well defined. The top of this member is situated at Restoration Point	1200
(E) Shaly sandstone gradually becoming more sandy in depth. Bedding planes very distinct	450
(F) Massive sandy shales. Bedding planes distinct	350
(G) Massive brownish gray coarse grained conglomeratic sandstones interbedded with bands of coarse conglomerates. Many of the pebbles of the conglomerate are composed of basalt and shale	1800
Total thickness	8900

The above described beds also occur in part in the exposures within the City of Seattle and in the Newcastle Hills. Fossils are fairly abundant in these strata and belong to the Acila gettysburgensis Zone.

One of the most complete sections within the state occurs at Cape Flattery and along the Strait of Juan de Fuca. Approximately 15,000 feet of Oligocene sediments have been deposited. The basal beds are largely shales which have been badly contorted in places. Above these are massive conglomerates forming the point of the cape. The upper part of the section is composed of alternating shales and sandstones. The detail of this area may be seen on Plate XVII.

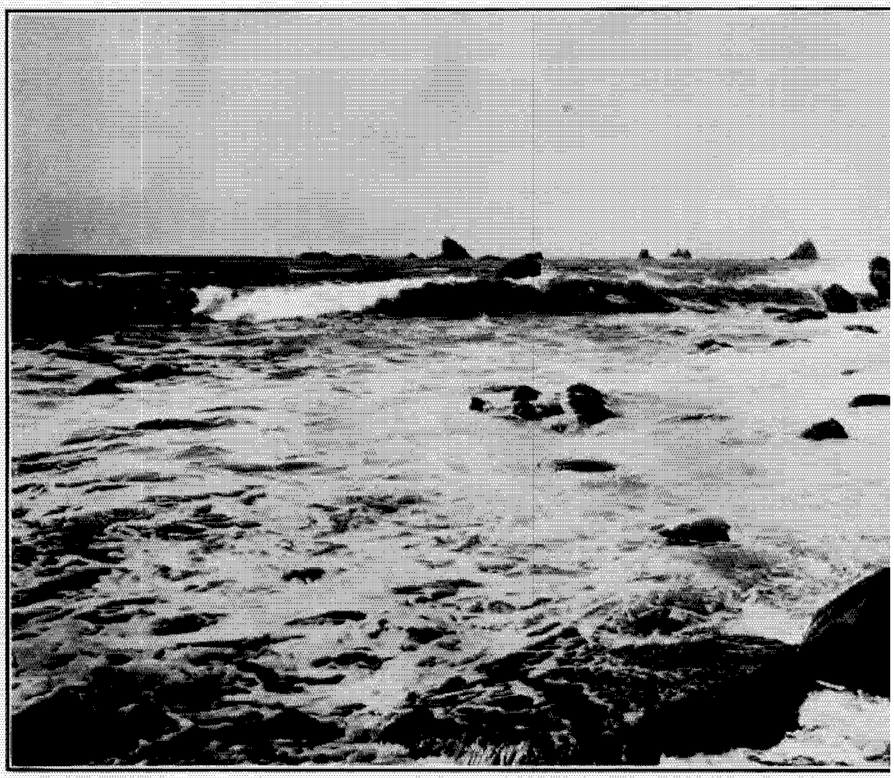
The following section is involved in Cape Flattery between the basal beds at Waatch Slough and the upper beds as exposed between Neah Bay and Sekiu River.

Top of Cape Flattery Section.	*Feet.*
Massive sandstone	700
Shale, but mostly covered	900
Massive sandstone	175
Shale, but mostly concealed	900
Massive sandstone	300
Concealed	500

Top of Cape Flattery Section.	*Feet*
Massive brown sandstone	300
Alternating beds of shale and sandstone	1200
Sandstone	200
Conglomerate	30
Sandstone	50
Conglomerate	50
Conglomerate and shale	500
Coarse conglomerate	300
Shale	700
Alternating beds of shale, sandstone and conglomerate	200
Massive sandy conglomerate	175
Hard flinty shale	200
Alternating shale and sandstone	300
Interbedded conglomerate and massive sandstone	450
Massive conglomerate	30
Massive sandstone and intercalated conglomerate lenses	300
Sandy conglomerate as exposed at the Cape	1400
Interbedded shale and sandstone	150
Shale, but mostly concealed	500
Banded sandy shale	200
Interbedded conglomerate and sandstone	250
Shale	350
Gritty sandstone with small amounts of interbedded shale	250
Shale	1200
Banded brown sandstone	100
Total thickness	12,860
Base of Cape Flattery Section.	

CONDITIONS OF DEPOSITION.

The Oligocene deposits of western Washington were entirely laid down in marine embayments. The character of faunas as well as the lithology of the sediments indicates deposition in moderately deep water. During the Oligocene the Cascade Mountains were not in existence. Their present site was a land area occupied in part by small fresh water lakes. Volcanic activity was more or less continuously taking place and the finer ashes may have in part been carried by the winds and dropped in the marine waters to the west. The northern Cascades were possibly much higher in elevation than the lake region of the central and southern Cascades. Presumably this region was being drained to the embayments of the ocean by streams heading in British Columbia or in eastern Washington. A considerable part of the sediments which forms the marine Oligocene deposits may have been derived from this area and have been transported westerly by stream action.



Interbedded Sandstones and Shales of Oligocene Age Exposed on the South Shore
Cape and Waatch Slough.

The Olympic Mountains and Vancouver Island were probably land areas. The Olympics were at least 1,000 feet lower in elevation than at present as marine deposits occur at that elevation where the wagon road from Clallam Bay to Forks crosses the main divide. Presumably the region had been partly reduced to a peneplain during the Cretaceous and Eocene and during the Oligocene the Strait of Juan de Fuca was depressed allowing marine sediments to form upon the submerged borders of the peneplain.

There are insufficient exposures to the Oligocene sediments to determine definitely the successive extent of the seas or embayments during the epoch. Sediments containing the Acila gettysburgensis Zone are much more widely distributed and are much thicker than those of the two lower zones. Apparently there was a partial withdrawal of the seas at the close of the Eocene and new invasion at the opening of the Oligocene. The embayments in which the Lincoln and Porter horizons were deposited were restricted in area and possibly did not cover the Puget Sound Basin area. During the upper Oligocene the larger part of western Washington west of the foothills of the Cascades was covered with the waters of the ocean. There may possibly have been a low land area connecting the Cascades with the Olympics in Pierce and southern Kitsap counties. This problem is still unsolved.

At the close of the Oligocene there was an emergence over a large portion of western Washington and all of the Puget Sound Basin became a land area. Embayments were still in existence in the Strait of Juan de Fuca region as well as in southwestern Washington.

For purposes of detailed description western Washington may be divided into several provinces. The following divisions will be used in the discussion of the Oligocene: King County-Restoration Point Area; Cape Flattery-Strait of Juan de Fuca Area; Quimper Peninsula Area; Grays Harbor Area and Columbia River Area.

KING COUNTY—RESTORATION POINT AREA.

GEOGRAPHIC DISTRIBUTION.

There is a prominent spur of the Cascade Mountains in King County between Snoqualmie and Green rivers which extends westerly to Lake Washington. It crosses Puget Sound Basin in part as a sub-glacial and in part as a submarine ridge. The rocks forming the ridge are of Eocene and Oligocene age. Within the Puget Sound Basin they are exposed in Issaquah Mountain, Newcastle Hills, the low hills of South Seattle and Alki Point, the low rock cliffs at the entrance to the Bremerton Navy Yard, the Bald Hills of central Kitsap County and the foothills of the Olympic Mountains between the Duckabush and Quilcene rivers. The greater portion of this ridge is buried beneath an enormous deposit of glacial drift.

The core and south flank of the ridge and spur are composed chiefly of Eocene lavas and sedimentary rocks. The north flank is in part composed of Oligocene sedimentary rocks. The most easterly Oligocene exposures occur on the eastern side of Lake Sammamish, in Section 16, Township 24 North, Range 6 East in the side of a small creek. Outcrops also appear in the logging road cuts and small canyons on the divide between Coal Creek and Lake Sammammish. Farther west there are exposures south of Kirkland, east of Mercer Slough. The same rocks are well developed around the shores of Bailey Peninsula and from that point southward to Rainier Beach on the west side of Lake Washington. Similar exposures of the same formation have been made in the street excavations of Columbia City, South Seattle and Georgetown. At Alki Point Oligocene sandstones and shales occur tilted almost vertically and form a low marine terrace about 15 feet above sea level. The rocks are exposed along the beach for a distance of approximately 1,500 feet. Similar low rock terraces occur along the south shores of Bainbridge Island as well as on the opposite shore of Rich Passage. The same formation appears six miles westerly along the shores of the narrow inlet between Bremerton and Silverdale. No more exposures occur as far as the

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Coarse Grained Oligocene Sandstones and Conglomerates Showing Cavernous We
South Side of Cape Flattery.

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south end of the Quimper Peninsula. East of Everett and south of Snohomish, at Fiddler Bluff, shales and sandstones of Oligocene age are exposed in the railroad and wagon road cuts. The surface formations on all sides of these outcrops for many miles are composed entirely of glacial drift.

STRATIGRAPHY.

The most complete section of the Oligocene deposits within the Puget Sound Basin is to be found at the entrance to the Bremerton Navy Yard. One generalized section has already been described in the general discussion of the Oligocene of western Washington. This section was constructed along the line B-B′, Plate IV.

The westerly continuation of the strata as exposed in section B-B′ reappear in the cross section A-A′. The upper beds exposed at Point Glover appear to be the equivalent of the beds in member (C) of the section B-B′. The extreme upper portion of member (G) as exposed at Orchard Point is the westerly continuation of the narrow conglomeratic layers occurring east of Bean Point on the south end of Bainbridge Island. The conglomerates outcropping at Quarry Point are the equivalent of those exposed at Middle Point. From Middle Point the same beds cross Rich Passage and appear in the cliffs at Fort Ward on the south shore of Bainbridge Island. Here they become less conglomeratic and more sandy. Near Restoration Point they are the equivalent of the upper portion of member (D). The shales and sandstones exposed between Point Glover and Middle Point are correlated with the sandy shales in member (C). The conglomerates in member (A) and the shales in member (B) do not appear on the south side of Rich Passage. It is possible that the conglomeratic sandstones and interbedded shales exposed near Tracyton and Phinney Point are the equivalent of members (A) and (B). The following stratigraphic section has been measured between the basal beds at Orchard Point and the higher beds exposed at Point Glover:

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Top of Section at Point Glover.	*Feet.*
Massive sandy shale with poorly defined bedding planes	150
Shaly sandstone	70
Brownish gray sandy clay shale	500
Massive brown sandstone	100
Gray sandy shale	45
Brown massive coarse grained sandstone	60
Interbedded shale and sandstone, shale predominating	140
Massive sandstone	80
Thickly bedded shale	200
Alternating beds of thinly bedded shales and sandstone	520
Banded shale and sandstone, shale predominating	40
Banded shale and sandstone	20
Thinly bedded gray shale	70
Massive brownish gray sandstone	40
Thinly bedded shale	30
Massive brown sandstone	300
Mainly shale, with a few narrow bands of interbedded sandstone	200
Mainly sandstone, with a few narrow bands of interbedded shale	30
Mainly clay shale	900
Massive brown sandstone	65
Alternating layers of thinly bedded sandstones and shales with occasional bands of sandstone four to five feet in thickness	90
Massive brown sandstone, slightly banded	75
Banded shale	10
Thinly bedded shaly sandstone	40
Alternating bands of thinly bedded shale and sandstone	75
Massive brown sandstone	20
Massive brown gritty sandstone	35
Gray shale possessing well defined bedding	100
Massive brown sandstone containing bands of shale	30
Mostly shale with a few bands of interbedded sandstones; strata largely concealed	1800
Thinly bedded shale somewhat massive in places and containing occasional bands of sandstone averaging one foot in thickness	320
Massive brownish gray sandstone containing pebbly and conglomeratic bands	1400
Massive conglomerates composed of pebbles ranging up to two feet in diameter and composed in part of altered basalt	15
Massive gritty sandstone	60
Conglomerate	15
Massive gritty brown sandstone—these are the lowest strata exposed in the Bremerton Inlet area	70
Thickness	7615

In other portions of the Puget Sound area only partial sections can be measured. The northern and central parts of Seattle are composed entirely of deposits of glacial drift of great thickness. The southern portion of the city is in part built upon bed rock formations of Oligocene age. A thin layer of drift is mantled over much of this. Over 1,000 feet of sand-

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stones and shales outcrop in the eastern wall of Duwamish Valley between Brandon Street and Georgetown. To the north the bed rock surface passes rapidly below sea level and is covered with over 800 feet of drift. To the south of Georgetown bedrock does not reappear for a distance of eight miles. Somewhere within this interval the contact between the Oligocene and Eocene formations lies buried.

One mile south of Georgetown, at South Park, on the west side of Duwamish River, three small rounded hills of sandstone and shale project through the alluvial covered floor of Duwamish Valley. These exposures together with those at Duwamish Station and Georgetown indicate that Oligocene bedrock exposures do not exist very deep below the floor of the valley.

In the street cuts of Columbia City, in South Seattle, shales and sandstones are exposed having a measured thickness of over 2,000 feet. A similar section exists to the east on the Bailey Peninsula where the deposits are in part composed of conglomerates. The strata outcropping in both of these localities are the eastern extension of those exposed at Georgetown as well as at the entrance to the Bremerton Navy Yard.

GEOLOGIC STRUCTURE.

In the discussion of the Eocene formations in King County a predominating anticlinal structure was described as trending east and west through South Seattle. The core and south flank was described as being composed of lavas and Eocene sediments. The north flank of the anticline is in part made up of Oligocene sandstones and shales which have just been described.

The principal structure consists of a predominating anticlinal axis referred to in this report as the Newcastle anticlinal axis, Plate IV, trending in a somewhat sinuous fashion through the Newcastle Hills westerly into South Seattle. It can be definitely traced from a point three miles east of Issaquah where it extends southwesterly to a point south of the same town. It crosses Issaquah Creek, passes through Squak Mountain and

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into the Newcastle Hills. The Eocene lavas forming the core of the anticline outcrop on the eastern shore of Lake Washington south of the mouth of Coal Creek. Mercer Island and a large portion of the hills south of Columbia City are composed mostly of glacial deposits. The probable position of the anticlinal axis has been drawn upon the map, Plate IV, from the structural evidence afforded by the occurrence of Oligocene shales and sandstones in Columbia City and the Bailey Peninsula.

Oligocene sediments are not known to occur on the south flank of the Newcastle anticline. It is possible that they may at one time have extended much farther to the south and have later been removed by erosion or the original shore line may have been not far south of the present Eocene-Oligocene contact. The westerly continuation of the anticlinal structure occurs in the Bald Hills of Kitsap County where it may be monoclinal.

The Oligocene sediments in the north flank of the anticline have been somewhat wrinkled and developed into minor folds. The axes of such folds have been inserted on Plate IV.

A broad synclinal fold with its axis pitching to the north has been formed in the region of Lake Sammammish. Its nose is about two miles south of the town of Issaquah. The strata involved in its eastern limb are exposed to the east of Issaquah at Grand Ridge and to the north in Section 13, Township 24 North, Range 6 East. They have a strike of North 60° East and dip to the northwest. The sandstones and shales forming the western limb of the fold outcrop in the vicinity of the Superior coal mine on Tibbett's Creek and westerly at Coal Creek and Newcastle. Observations taken in the rock tunnels of the Coal Creek mine and along Coal Creek give strikes ranging from North 85° West to North 55° West. The dip varies from 40° to 70° to the northeast.

A second synclinal fold has been formed in the vicinity of Columbia City and South Seattle. Its axis also pitches northerly. The strata involved in the eastern limb outcrop in the

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western portion of Columbia City and along the shores of the Bailey Peninsula where the prevailing strike is North 70° East and the dip 60° to the northwest. The sandstones and shales exposed within and to the west of Columbia City form the western limb and have a prevailing strike North 70° West and a dip of 70° to the northeast. The structural conditions at the Bailey Peninsula and along Coal Creek suggest the presence of a minor anticlinal fold in the near vicinity of Mercer Island.

A third synclinal fold lies in Duwamish Valley. Its eastern limb is composed of strata exposed in the bluff along the eastern side of Duwamish Valley from Brandon Street to Georgetown. Between Brandon Street and the Archer Blower Iron Works the beds have a strike of North 25° East and a dip of 28° to the northwest. To the south in the vicinity of Georgetown the strike is more nearly north and south. South of Georgetown the strike is North 25° West and the dip 35° to the southwest. The nose of the fold is near Duwamish Station. The western limb is formed of rock outcrops in the three hills at South Park and Alki Point. At the former locality the strike is North 50° West and the dip 50° to the northeast. The hills between Duwamish Valley and Admiralty Inlet are entirely composed of deposits of glacial drift. The structural conditions on the eastern side of Duwamish Valley and in the western part of Columbia City indicate the existence of a minor anticline in the ridge between.

Excellent exposures of the Oligocene strata occur on the south shore of Bainbridge Island as well as to the south on the opposite shore. The structural relations may be seen on Plate XXIV. A minor anticlinal fold occurs between Point Glover and Middle Point on the south of Rich Passage. A small synclinal fold exists on the south end of Bainbridge Island between Pleasant Beach and Bean Point. From Point White westerly no Oligocene deposits are exposed as far as Tracyton. In the vicinity of Tracyton sandstones and shales outcrop along the water's edge for a distance of a mile. No further exposures

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occur as far as the west side of Hood Canal with the exception of glacial drift.

To the north of the area described in both King and Kitsap counties no bedrock outcrops at the surface. The Oligocene formations in the north flank of the Newcastle anticline, from structural conditions occurring at the surface, must extend very deep. Presumably there is a major synclinal trough trending east and west and eight or ten miles to the north of the surface exposures. Such a trough does exist between Port Discovery Bay and Quilcene Bay in Jefferson County. The strata involved in the south flank of this trough are the westerly continuation of those exposed at the entrance to the Bremerton Navy Yard. Those on the north flank are probably the equivalent of deposits which are presumed to exist far below sea level in northern Kitsap and King counties.

Between Duwamish Station and Renton and easterly to Cedar River folds have been formed but the strata involved are of Eocene age. It is possible that small outliers of Oligocene sediments may exist but as yet they have not been discovered.

Fossil marine invertebrates are abundant and fairly well preserved in certain localities in this area. There is very little variation in the faunas from the upper to lower beds. They represent the Acila gettysburgensis Zone. The Molopophorous lincolnensis and Turritella porterensis zones are absent or at least have not as yet been recognized.

QUIMPER PENINSULA AREA.

GEOGRAPHIC DISTRIBUTION.

The Quimper Peninsula forms the extreme northeastern corner of the Olympic Peninsula. The surface exposures over most of this area consist of sands, clays and gravels of glacial origin. At several localities along the shore and in the small creek canyons there are exposures of lavas and sedimentary rocks of Eocene and Oligocene age. The former have been described in the previous chapter. From Hood Head on Admiralty Inlet a belt of Eocene lava and tuffs four miles wide

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extends northwesterly across the peninsula to the south end of Port Discovery Bay. They continue as a narrower belt from the western shore of Port Discovery Bay to Sequim Bay. These rocks constitute the core or axis of an anticline which to the east in Kitsap County does not appear at the surface. Sandstones and shales of Oligocene age rest upon both the northeastern and southwestern flanks. The former outcrop at the water's edge along the shore of Oak Bay, Scow Bay, the southern part of Port Townsend Bay and the middle shores of Port Discovery Bay. The latter are exposed at the south end of Port Discovery Bay and along the cuts of the Port Townsend and Southern Railway as far as Quilcene. The area between the railroad and the central core of Eocene lavas is largely covered with glacial drift. To the southwest of Quilcene Eocene lavas reappear as the surface exposures where not covered with drift. The contacts as drawn upon Plate IV are provisional since they are in most places concealed beneath deposits of drift.

GEOLOGIC STRUCTURE.

A synclinal and an anticlinal fold constitute the predominant structural feature of this area. The approximate position of the anticlinal fold has been described. The synclinal fold is to the southwest of the former and trends from southeast to northwest. The trough is from six to eight miles in width but narrows from the southeast to northwest. The strata outcropping along the railroad from Quilcene to Port Townsend Bay form its southwestern limb. The sandstones and shales exposed from Crocker Lake to Fairmont on the shore of Port Discovery Bay are a part of the northeastern limb. This syncline is probably the northwestern continuation of the one in Kitsap and King counties lying north of the Newcastle anticline and buried beneath an enormous thickness of glacial drift. Its south limb is composed of strata which are an extension of the Oligocene at Bremerton Inlet, Seattle and the Newcastle Hills.

About five miles northeast of Quilcene sandstones outcrop on the wagon road to Dabop Bay. The hills on the west side

DNR-00005183

Sandstones and Conglomerates of Lower Miocene Age as Exposed East of
Strait of Juan de Fuca.

DNR-00005184

of Crocker Lake have excellent exposures of shale and sandstone. They strike northeast and southwest and seem to be passing around the nose of the syncline.

North of Hood Head partially stratified tuffs and intercalated lavas are dipping to the north at an agle of 28°. About one mile north of Olele Point Oligocene shales are resting upon the lavas and dipping north at an agle of 8°. From that point to the south end of Port Townsend Bay shales with alternating beds of sandstone have an average angle of dip to the north of 15°. Along the shores of the southern end of Port Townsend Bay and Scow Bay the sedimentary rocks are interbedded shales and sandstones.

On the eastern shores of Port Discovery Bay gray sandstones outcrop at the water's edge just north of Woodman Station. They are resting nearly flat but in places are slightly undulating. Massive clay shales are exposed on the opposite western shore of the bay.

Poorly preserved fossils occur scattered through the strata at different localities. They are most abundant north of Woodman Station on Port Discovery Bay and near the north end of Oak Bay. The species are somewhat different from those in the Acila gettysburgensis Zone and seem to have closer affinities with the Turritella porterensis and Molopophorous lincolnensis Zone.

CAPE FLATTERY-STRAIT OF JUAN DE FUCA AREA

GEOGRAPHIC DISTRIBUTION.

The area involved extends from Port Crescent westerly to Cape Flattery, a distance of fifty miles. The belt is six to eight miles in width. It forms the north coastal border of the Olympic Peninsula. The surface exposures are almost entirely composed of glacial drift. The Oligocene rock outcrops are confined to the shore line and the canyons of the creeks draining to the Strait of Juan de Fuca. With the exception of the divide extending to Cape Flattery the average elevation is 400 feet above sea level. The contact between the Eocene and Oligocene, which has been designated upon the map, Plate IV,

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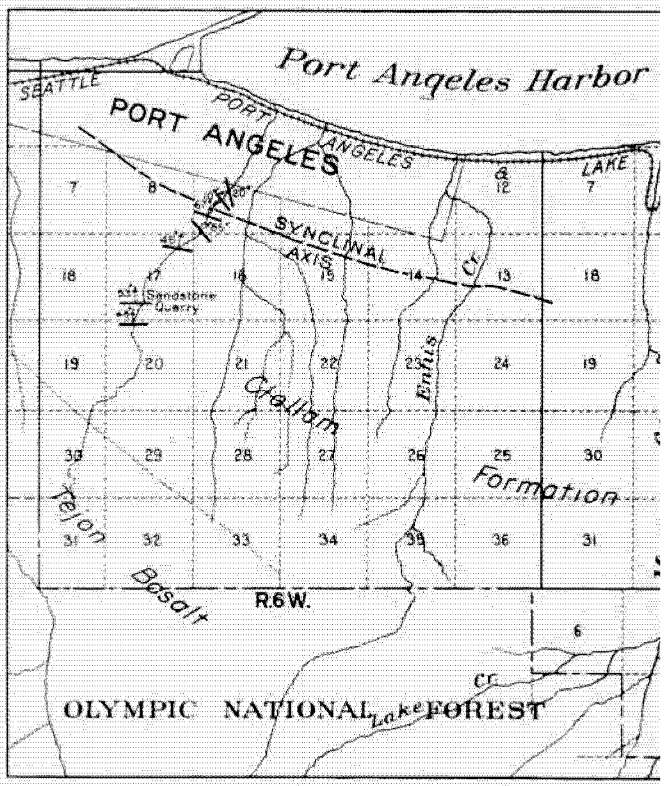
is provisional. On the coast south of Cape Flattery it can be definitely established one mile north of Portage Head. It occurs near the falls on Hoko River in Section 24, Township 31 North, Range 14 West. Between Hoko River and the ocean a detailed search has not been made. The region is heavily timbered and covered with glacial gravels. The contact crosses the Forks-Clallam Bay wagon road just south of the divide and continues westerly north of Solduck River to Lake Crescent. The line as drawn upon the map is only approximate and should not be accepted as accurate. Exposures of lava occur in the wagon road cuts on the north side of Lake Sutherland in Section 21, Township 30 North, Range 8 West. From Lake Sutherland the contact trends northwesterly and reaches the coast at a point two miles west of Port Crescent.

GEOLOGIC STRUCTURE.

Both the Oligocene and Eocene deposits on the north shore of the Olympic Peninsula are involved in a large synclinal trough the axis of which trends from Lake Sutherland northwesterly diagonally across the Strait of Juan de Fuca. The northeastern limb of it is represented as a narrow fringe on the opposite shore of Vancouver Island. The southwestern limb has just been described as forming the north border of the Olympic Peninsula. The strata involved within it are 19,000 feet thick, 15,000 feet of this amount consisting of shales and sandstones of Oligocene age. Above these there are 4,000 feet of lower Miocene sandstones and shales exposed on the shore of the Strait of Juan de Fuca between Pysht and Clallam Bay.

On the southwestern flank of the major syncline ten transverse minor anticlinal and synclinal folds have been developed between Crescent Bay and Cape Flattery. Their average trend is about North 15° East. The nose of the major syncline where the Oligocene beds rest upon the Eocene basalts is situated in Section 19, Township 30 North, Range 8 West. The axis of the syncline crosses the county wagon road in Section 6, Township 30 North, Range 9 West, and extends northwesterly, intersecting the coast one mile west of Gettysburg. The shales



Geologic and Structural Map Southwest of Port Angel on the eastern limb have an average strike of North 60° West and dip to the southwest at an angle of 18°. The strata involved in the western limb have a prevailing strike of North 75° West with a dip ranging from 13° to 45° to the northeast. In the vicinity of the point where the synclinal axis emerges at the Strait of Juan de Fuca an anticlinal axis also emerges with a trend North 30° East. The strata forming the western limb of the anticline are exposed in the bluffs along the shore for a distance ten miles west of Gettysburg. The prevailing strike is North 60° East and the dip 13° to 45° to the northwest.

In the bluff just west of Twin River sandy shales occur striking nearly north and south with a dip of 15° to the west. Farther to the west the first exposures encountered are about one and one-half miles west of Deep Creek with a strike of North 30° West and a dip of 30° to the southeast. On the basis of this evidence and a similarity of the stratigraphic sections a synclinal trough is believed to trend nearly parallel to Deep River. A small anticline exists one and one-half miles east of Pysht. From Pysht to Clallam Bay the exposures along the shore of the strait are of lower Miocene age.

From the mouth of Sekin River to Cape Flattery the strata are entirely of Oligocene age. The structure is mainly monoclinal. The sandstones and shales involved in the monocline are in reality the southwestern limb of the major syncline previously described. Observations taken on strike and dip along the Clallam Bay-Forks wagon road for a distance of five miles from Clallam Bay give an average strike of North 60° West and a dip of 40° to the northeast. On Pysht River in Section 23, Township 31 North, Range 12 West the strike is North 35° West and the dip 32° to the northeast. Two miles south of this point they begin to appear along the wagon road and continue to the main divide. In the western part of Section 26, Township 31 North, Range 12 West, the strike of the shales ranges from North 6° West to North 30° West with a dip of 45° to the northeast. Just south in Section 35 the strike becomes North 70° West and the dip 60° to the northeast.

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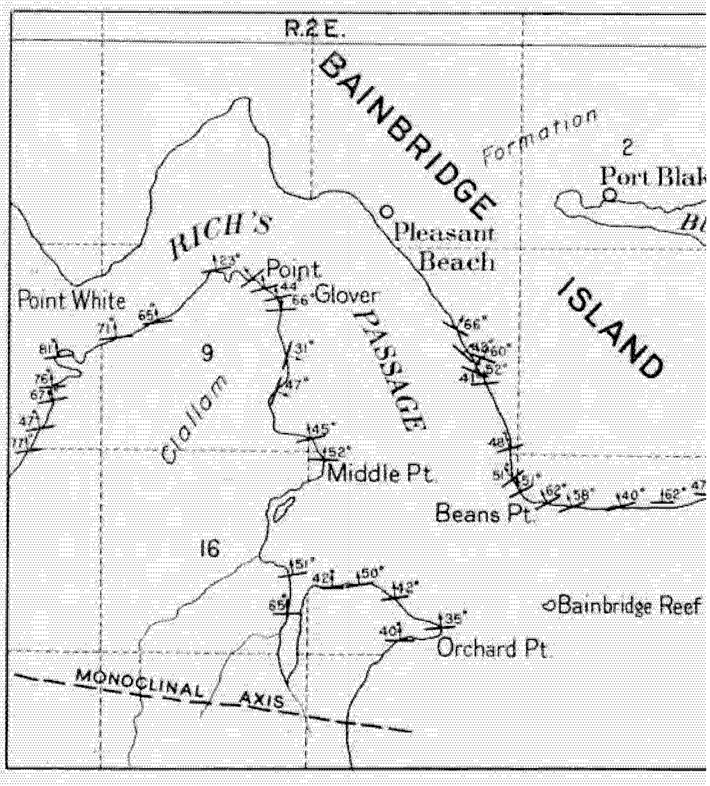
Along the shores of Cape Flattery the strike varies from North 70° West to North 30° West with a constant dip to the northeast ranging from 20° to 70°. At the extreme point of the cape the dip is nearly flat in places and on Tatoosh Island the strike is North 30° East and the dip 20° to the southeast. South of the cape near the mouth of Sooes River the strata have an average strike of North 45° West with a dip ranging from 20° to 80°. Observations taken in the cliffs along Waatch Slough conform in general to those around the shores of the cape.

Between Sooes River and Portage Head the Oligocene deposits are covered with Pleistocene sands and gravels, so that the structure cannot be determined. At Portage Head badly altered basalts of probable Eocene age form prominent outcrops. It is possible that a fault extends from the north end of this head southeasterly along the main divide. If so the Oligocene deposits may have been dropped to the north as a block. Between Portage Head and Point of the Arches, Oligocene strata outcrop along the beach for a distance of three miles. They have been folded into a synclinal trough whose axis trends North 45° West and intersects the coast line in Section 19, Township 32 North, Range 15 West. The strata forming the north limb strike North 35° West and dip at an agle of 65° to the southwest. Those in the south limb have a strike of North 40° West and dip 45° to the northeast. No determination has been made as to how far these deposits extend to the southeast.

The Oligocene deposits on the north shores of the Strait of Juan de Fuca opposite Cape Flattery outcrop at intervals from Sooke Bay westerly to Carmanah Point. They rest unconformably upon Carboniferous and Mesozoic metamorphics together with Eocene lavas and tuffs.

FAUNA.

The shales exposed between Crescent Bay and Gettysburg and along the north shores of Lake Crescent contain a small fauna more closely allied to the Turritella porterensis Zone



Geologic and Structural Map in the Vicinity of the Entrance to t than to the Acila gettysburgensis Zone. The shales occurring along the shore south from Cape Flattery are presumably of the same horizon. The exposures between Twin and Pysht contain a fauna typical of the Acila gettysburgensis Zone. The strata are the equivalent of those in Kitsap and King counties. The fauna occurring in the shales and sandstones between Sekiu River and the extreme point of the Cape belong to the same zone. The massive sandstones and shales exposed between Pysht and Clallam contain a lower Miocene fauna. The contact relations between the lower Miocene and the Oligocene at Pysht and Clallam Bay are uncertain. There appears to be a fault contact just east of Pysht. Presumably the two formations are unconformable. At the time when the maps accompanying the report were made the strata containing the Acila gettysburgensis Zone and the Turritella porterensis Zone were thought by the writer to be lower Miocene. As a result, they, together with the Arca montereyana Zone as exposed between Pysht and Clallam Bay are included in the Clallam formation. In the revised grouping the Arca montereyana Zone or lower Miocene is not included within the Clallam formation. The Clallam formation as previously defined is restricted to the Oligocene marine deposits.

A list of the faunas occurring at the localities along the Strait of Juan de Fuca are given in the Faunal lists of the Oligocene on page 170.

GRAYS HARBOR AREA.

GEOGRAPHIC DISTRIBUTION.

The Oligocene deposits of the Grays Harbor area involve approximately 600 square miles of territory. They lie in contact with the overlying upper Miocene deposits and to the south and east with the Tejon formation. The area indicated upon Plate III as the Lincoln formation should also be grouped with the marine Oligocene for discussion. The larger part of the area is heavily covered with forest and such rock exposures as occur are usually deeply altered and converted into soil. The tracing of contacts upon the surface becomes exceedingly dif-

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ficult. The contacts as designated upon Plate III are only approximate. Observations were made on the different creeks and the positions of contact noted where possible. Such points were connected by provisional contact lines. Large portions of this area are entirely devoid of surface rock exposures but wherever conditions warranted it the probable underlying bed rock formations were given the preference in mapping. Where it was impossible to determine the character of the underlying formations the surface gravels or sands were mapped.

Beginning at Grays Harbor and passing southerly, the contact of the Oligocene shales and sandstones may be seen on North River in the northwestern corner of Township 15 North, Range 9 West. South of this locality the exposures are concealed. The contact crosses Willapa River about halfway between South Bend and Raymond. To the north and south of the city of South Bend basaltic rock appears in places which are presumably of Eocene age. To the south of Raymond a survey was made up the south fork of Willapa River and the contact determined as indicated upon Plate III. Several basalt flows are intercalated with shales. Fossils are absent and the uppermost lava flow was chosen as the base of the Oligocene formations. From Trap Creek the contact swings more nearly east and follows the foothills about two miles south of the South Bend branch of the Northern Pacific Railway. In Willapa River at Holcomb there are basaltic tuffs and lavas whose stratigraphic position could not be definitely determined. The contact was drawn two miles south of Holcomb on the basis of finding a few species of Oligocene fossils on Trap Creek. A contact was observed in the cuts of the railway just west of Pluvius Station on the divide between the headwaters of Willapa and Chehalis rivers. From this point it swings northerly as an irregular line and follows roughly the divide between Chehalis and North rivers. It passes the headwaters of Vesta, Pioneer and Martin creeks on the southwest and Rock and Garrard creeks on the northeast. It continues on to the northwestern side of Chehalis Valley which it crosses near the junc-

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tion of Rock and Cedar creeks. Thence it extends northwesterly until it disappears beneath the drift covered areas of Mason County.

Basalt occurs along the divide between Fall River and Wilson Creek in the northwest corner of Township 14 North, Range 6 West. This has been mapped as Eocene but may possibly be a Miocene flow. If so it lies in contact with the Eocene basalts to the east and cannot as yet be separated from them. The north limits of the Oligocene deposits lie in close proximity to Chehalis River. The contact crosses east of the town of Montesano and swings past Bitter Creek and Wynoochee River in the north central part of Township 18 North, Range 8 West. West of this place it turns south and crosses Chehalis River east of Cosmopolis.

The strata occurring in the south halves of Township 17 North, Ranges 7 and 8 West are in part lower Miocene. On Plate III it is included with the Clallam formation. Insufficient information is available to determine its areal limits.

GEOLOGIC STRUCTURE.

The Oligocene deposits of the Grays Harbor area have been folded into a series of nearly parallel anticlines and synclines trending approximately North 50° West. Three synclinal troughs have been developed. The most southerly of the three extends from the headwaters of Willapa River northwesterly to Grays Harbor. The south limb resting upon Eocene basalts, is composed of sandy shales and sandstones which near the town of Willapa have a strike nearly north and south and a dip varying from 10° to 20° to the east. Survey traverse lines were made up Mill Creek and the data obtained has been platted upon Plate III. The strata have an average strike of North 60° West and a dip of 20° to 30° to the northeast. Nearly all the observations recorded between Willapa and Francis show a prevailing northwest strike and a dip to the northeast. Rock exposures forming the north limb may be seen in the stream canyons on the road from Willapa to Brooklyn. The average strike is North 45° West and the dip 20° to the southeast. Observations made on the same limb along North River in Township 16 North, Range 9 West show prevailing strikes of North 60° West and dips ranging from 18° to 34° to the southwest.

A second synclinal trough trends from the headwaters of North River northwesterly to Montesano. Both flanks are dipping at very low angles towards the axis and the trough itself is pitching to the north. South of Chehalis River in Township 17 North, Ranges 7 and 8 West, the strata become nearly flat and finally develop into four minor short folds all trending northwesterly. The eastern limb of the main trough may be cut off from the underlying basalts by a fault trending diagonally across Township 16 North, Range 6 West.

To the northwest of Montesano the Oligocene is fairly well exposed in places and while the strata are not sharply folded yet there are undulations which may be definitely traced as anticlinal and synclinal troughs. The positions of these folds have been designated upon Plate III.

Outcrops are well exposed along the O.-W. R. R. & N. Co. track between South Elma and Cosmopolis. The strata involved are presumably of lower Miocene age but they are grouped with the Clallam formation on Plate III. About three miles east of South Montesano an anticline crosses Chehalis River trending North 55° West. Exposures of the northeastern flank in the O.-W. R. R. & N. Co. cuts strike North 50° West and dip 15° to the northeast. In the southwestern limb the dip is 30° to the southwest.

Three miles west of this anticline and south of Montesano the nose of a synclinal trough has been developed. It pitches South 45° East. On the northeastern side of the synclinal nose the sandstones and shales strike North 50° West and dip 35° to the southwest. To the west the strike gradually becomes more westerly until due south of Montesano it swings around and becomes north and south, with a dip of 30° to the east. In the grade cuts on Clemmon's logging road in Sections 19 and 20, Township 17 North, Range 7 West, the average strike is North 60° West and the dip ranges from 15° to 25° to the northeast.

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To the west of this synclinal axis a nearly parallel anticline crosses Chehalis River one-half mile east of Melbourne. It trends northwesterly and then turns and crosses Wynoochee River two miles south of its junction with Bitter Creek. Three miles farther west there is a synclinal trough and west of this the upper Miocene deposits rest upon the Oligocene and lower Miocene strata unconformably.

A small anticline crosses Wynoochee River in Section 16, Township 18 North, Range 8 West. The strata on the north flank dip at an angle ranging from 8° to 15° to the northeast while those on the south flank have a dip of 21° to the southwest. About one mile south a shallow syncline has been formed with a trend of approximately North 65° West.

In the southeastern part of Grays Harbor County a synclinal trough has been developed in the valley of Chehalis River from Oakville to Elma. It trends North 40° West and pitches to the northwest. The strata involved belong to the middle Oligocene or Turritella porterensis Zone. They are resting upon the Eocene basalts which are exposed at Oakville and in the Black Hills. On the east side of Chehalis River there are bluffs of sandy shale having a strike of North 30° East and a dip of 6° to 10° to the northwest. Three miles to the north, on Porter Creek, the dip increases to 40°. At this locality layers of basalt are interbedded with the sediments. No fossils occur and it is not certain whether the interbedded sediments are Oligocene or Eocene. To the northeast the Oligocene deposits are covered with sandstones and shales of upper Miocene age. The south limb of the syncline has a prevailing dip to the northeast, although in places as on Rock Creek in Section 17, Township 16 North, Range 5 West, it is nearly horizontal or undulating. On Lankner Creek in Sections 25 and 26, Township 17 North, Range 6 West, the shaly sandstones have a strike of North 60° West and a dip ranging from 10° to 16° to the northeast. North of Delazine Creek upper Miocene deposits overlie the Oligocene.

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A small isolated exposure of lowermost Oligocene occurs in southwestern Thurston and northwestern Lewis counties. The area is designated upon Plate III as the Lincoln formation. More recent studies since the completion of the maps have proven that the Lincoln formation is lowermost Oligocene and represents the Molopophorous lincolnensis Zone or the Lincoln Horizon. The deposits are at least 800 feet thick and are involved in a northwesterly trending shallow trough. Observations taken on the strike and dip between Lincoln Creek and Helsing Junction show a prevailing dip ranging from 4° to 12° to the southwest. At a point three miles above the mouth of Lincoln Creek the strata are dipping to the northeast. For some distance west of Helsing Junction the predominant dip is to the east and northeast, at angles ranging from 60° to 40°. The approximate position of the axis of this trough has been designated upon Plate III.

A small exposure of sandy shale occurs in the banks of Olequa Creek two miles south and west of Winlock. The fossils collected belong to the Molopophorous lincolnensis Zone. The surrounding country is deeply buried with gravels and sand and the lack of surface rock outcrops prevents areal mapping. The strata have an average strike of North 20° West and a low dip to the northeast.

COLUMBIA RIVER AREA.

GEOGRAPHIC DISTRIBUTION.

The Oligocene and lower Miocene deposits have been mapped as the Clallam formation in this area. With more detailed field studies in the future it may be possible to make a separation. These deposits occupy a belt along the north side of Columbia River roughly 45 miles in length by 10 miles in width. The belt extends in a nearly east to west direction from the ocean to within ten miles of Cowlitz River. At the eastern end it is only two miles in width, while at Shoalwater Bay it is over 15 miles. The contacts in most places are only approximate. It is possible that some of the lavas occurring on Nasel River which have been mapped as Eocene are in reality Oligocene. The

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northern contact has been drawn two miles north of the mouth of Nasel River at the base of the basaltic ridge. Oligocene shales outcrop at the mouth of the river and at various points along its course. Basalts also occur along the river at certain points. One of these is in Section 20, Township 11 North, Range 8 West in a deep canyon. The rock is an agglomeratic tuff with intercalated narrow tongues of lava. The lavas have been mapped as Eocene and the sedimentary rocks as Oligocene on the basis of faunas. Just above the mouth of Alder Creek there are a few poorly preserved fossils occurring in the tuffs which may be Oligocene. The Eocene-Oligocene contacts have been located on both the left and main forks of Grays River as well as on Skamokawa and Alockaman rivers. Marine Oligocene fossils occur in Section 6, Township 9 North, Range 4 West, on the west branch of Abernathy Creek. Sediments of a similar character containing a similar fauna occur on Germany Creek, seven miles from its mouth. Doubtless small patches as yet undetected exist farther to the east.

The south contact of the Oligocene and the underlying basalts crosses Alockaman River in Section 2, Township 9 North, Range 5 West. A narrow belt of basalt trends parallel to Columbia River from Skamokawa to Altoona. The contact with the Oligocene sediments on the north is indefinite. It is in part complicated by faulting.

Massive cliffs of basalt form the cape at the north entrance to Columbia River. Stratigraphically above the basalts are tuffs and interbedded shales containing lower Oligocene fossils. At Fort Columbia opposite Astoria, massive tuffs are exposed forming the core of an anticline. Shales and massive sandstones rest upon them. These are presumably Eocene but no fossils were found to prove their age. They may possibly be interbedded with the lower Oligocene sediments. No attempt has been made to differentiate them from the Clallam formation. Narrow dikes of diabase cut the Oligocene strata between Knappton and Grays Bay. One of the largest of these dikes outcrops on the north shore of Columbia River in Section 11, Township 9 North, Range 9 West.

Basalts occur intercalated with the shales and sanstones exposed at the south end of Long Island in Shoalwater Bay as well as along the shores of Long Island Slough.

The Oligocene formations exposed in this area consist of massive sandy shales, and interbedded narrow bands of shale and sandstone. Some of the shale bands are thinly bedded and occasionally calcareous. East of Knappton on the north shore of Columbia River small nodules occur in the shale bands. These are decidedly calcareous and usually contain at their centers a small fossil or pebble. The surface rock exposures are usually deeply altered and often entirely converted to soil.

GEOLOGIC STRUCTURE.

The Oligocene and lower Miocene strata of this area have been folded into a trough-like basin extending nearly east and west. Within this trough subsidiary anticlinal and synclinal folds have been developed all of which have a prevailing northwest to southeast trend. In Wahkiakum and Cowlitz counties the axes of the folds have an average trend of North 60° West. To the west in Pacific County they swing more to the northwest. An examination of the cliffs along the north shore of Columbia River indicates a syncline to intersect the shore in Section 1, Township 9 North, Range 9 West. The intervening area northward to Nasel River is barren of outcrops of such character that observation on strike and dip can be obtained. The syncline probably crosses the river in Section 4, Township 10 North, Range 9 West. From observations taken along the shore of Columbia River west of Knappton an anticline seems to exist with a northwesterly trend toward Shoalwater Bay.

An examination of the small creeks emptying into Wallicut River indicates the presence of a syncline between Bear River and Ilwaco with a trend of North 35° West. The more prominent folds of this area have been inserted on Plate III. A more detailed examination of the district would probably show many other minor folds provided sufficient rock exposures could be found.

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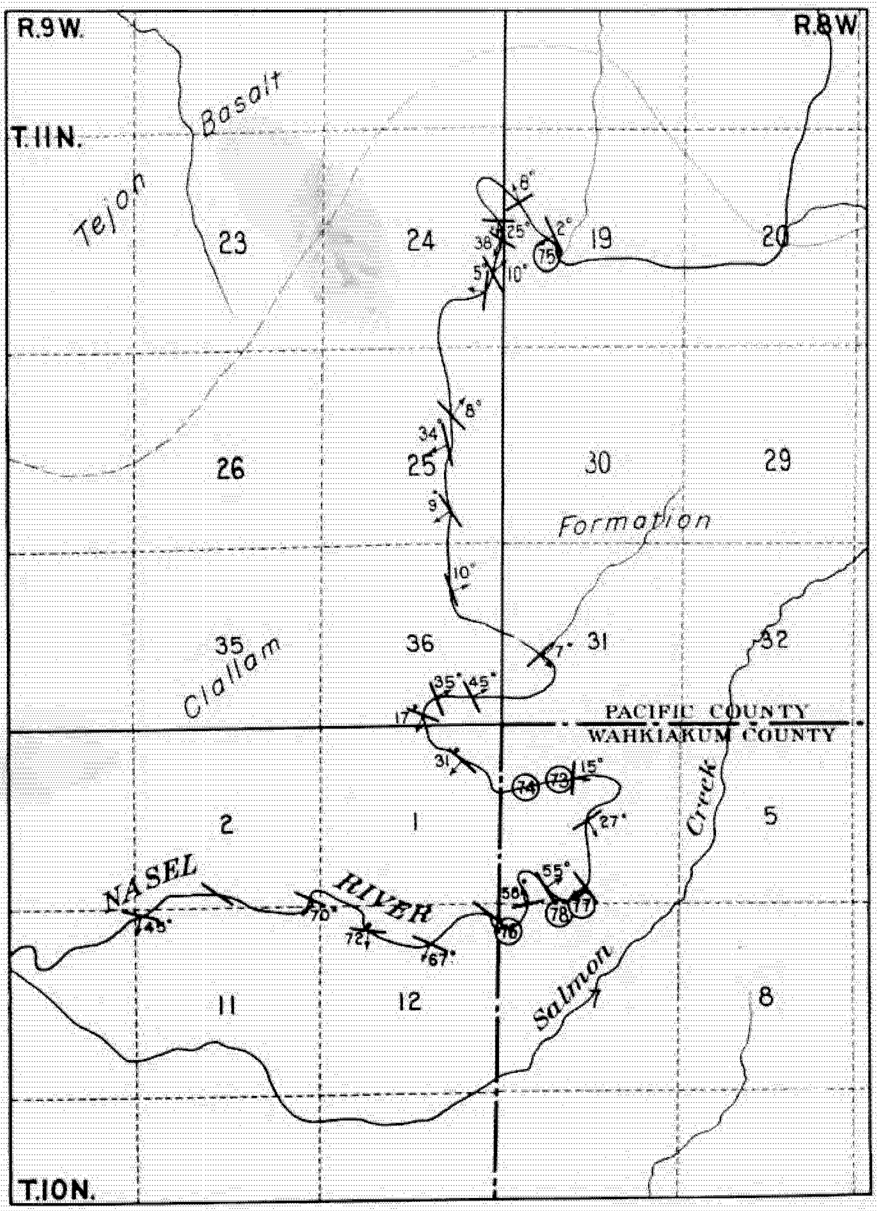

Geologic and Structural Map Along Portion of Nasel River, Pacific County.

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CHAPTER V.

MIOCENE FORMATIONS.

GENERAL STATEMENT.

Recent faunal evidence indicates that a part of the deposits of western Washington formerly regarded by the writer as lower Miocene are in reality Oligocene. The extreme upper portion of the Clallam formation as designated upon Plate IV is characterized by the Arca montereyana fauna. The term Clallam formation is now restricted to the Oligocene and the Arca montereyana Zone or Wahkiakum Horizon is retained in the lower Miocene.

There is a marked unconformity between the formations of the lower and upper Miocene. The former occur in Clallam County between Pysht and Clallam Bay as well as in Grays Harbor County between Montesano and Cosmopolis. Exposures also are present in Wahkiakum County on Alockaman River twelve miles north of Cathlamet. The upper Miocene deposits are confined to the Grays Harbor region and a small area in southwestern Clallam County near the mouth of Quillayute River. The total maximum thickness of the Miocene sediments is not over 8,000 feet.

LOWER MIOCENE.

GEOGRAPHIC DISTRIBUTION.

The massive sandstones and shales outcropping along the shore of the Strait of Juan de Fuca between Pysht and Clallam Bay contain a fauna distinct from the older Oligocene faunas as well from the younger upper Miocene faunas. The rocks are predominantly massive brownish gray sandstones which in places become grits or conglomerates. They exhibit distinct cross-bedding and give the appearance of having been deposited partly in the form of sand dunes. Carbonaceous bands occur occasionally. In Section 25, Township 32 North, Range 12 West a coal seam is interbedded with the massive sandstones and has at former times been worked on a commercial scale. The lower Miocene deposits of this area were largely formed under shallow water conditions.

The lower Miocene of the Chehalis Valley between Montesano and Cosmopolis is predominantly composed of massive sandy shales and shaly sandstones. They contain deeper water marine faunas than at Clallam Bay. The structural conditions occurring in this area have been described in the discussion of the Oligocene. The lower Miocene sandstones and shales outcropping on the banks of Alockaman River in Wahkiakum County have also been referred to and described in the chapter on the Oligocene.

GEOLOGIC STRUCTURE.

Seven anticlinal and synclinal folds have been developed in the sandstones exposed between Pysht and Clallam Bay. One mile east of Pysht River an anticline trends North 15° West. The strata in the eastern limb strike North 10° West and dip 55° to the northwest. Immediately west of this locality and east of the bluff at the mouth of Pysht River, the strike is North 22° East and the dip 75° northwest.

At Pillar Point there are massive sandstones in which a sharp synclinal fold has been developed. The eastern limb at Pillar Point stands nearly vertical and in places is even overturned. About one and one-half miles west of Pillar Point a shallow anticline has been formed with a northeasterly trend. The two limbs are each dipping away from the axis at angles of 15°. From this point westerly to the northwest quarter of Section 31, Township 32 North, Range 13 West, the dip continues westerly but increases to 60°. At this locality there is a closely folded syncline with a northeasterly trend. Both limbs dip 45° to the axis. Fifteen hundred feet west the same strata are folded into an anticline on the township line between ranges 11 and 12. The axis is just one-half mile east of the Clallam Bay coal mine. The strata east of the mine strike North 12° East and dip 15° to the northwest. West of the mine there is a small local fault. Four thousand feet west of the coal mine the sandstones are again folded into a synclinal trough. The eastern limb strikes North 26° East and dips 15° to the northwest, while the western limb trends North 75° West and dips to the northeast at an angle of 30°. One mile west, the beds swing and strike North 12° East with a dip of 20° to the southeast. Immediately west the same strata are again folded into an anticline and from its axis west to Slip Point the prevailing strike is North 80° West with a northeasterly dip of 60°.

A complete list of the fauna occurring within the lower Miocene is included in the faunal table of the Oligocene. The following species are among the most common within the Arca montereyana Zone: *Arca montereyana* Osmont, *Chione securis* Shumard, *Diplodonta parilis* Conrad, *Pecten propatulus* Conrad, *Pecten fucanus* Arnold, *Tellina arctata* Conrad, *Panope generosa* (Gould), *Phacoides acutilineatus* (Conrad), *Spisula albaria* (Conrad), *Tellina oregonensis* Conrad, *Venericardia quadrata* Dall, *Chione olympidea* Reagan, *Chione clallamensis* Reagan, *Ficus clallamensis* Weaver, *Crepidula praerupta* Conrad, *Fusinus stanfordensis* (Arnold), *Polynices saxea* (Conrad), *Sinum scopulosum* Conrad, *Dentalium conradi* Dall and *Aturia angustata* Conrad.

UPPER MIOCENE

MONTESANO FORMATION

Geographic Distribution.

The Montesano formation consists of an assemblage of conglomerates and sandstones with subordinate amounts of shale. The deposits attain a maximum thickness of 5,400 feet. They are limited in distribution, being confined to two widely separated areas. The larger is situated in the Grays Harbor region and for the most part north of Chehalis River. The smaller is in southwestern Clallam County in the vicinity of the junction of the Soleduck and Bogachiel rivers. The exact areal limits of the latter are indefinitely defined.

Lithology.

The formation in the Grays Harbor region consists of a thick series of moderately consolidated coarse grained, cross-bedded, brownish gray sandstones which in places become gritty

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or even conglomeratic. The conglomeratic belts usually occur in the form of lenses or tongues. The sandstones often are shaly and in the canyon of Wishkah River pass into clay-shales. In the canyons of the two forks of Humptulips River interbedded narrow bands of shale and sandstone are common.

In the Quillayute area shaly sandstones and gritty conglomerates predominate. Shales and sandy shales occur sparingly. The sandstones are commonly cross-bedded. No igneous materials of contemporaneous origin are known to occur.

Stratigraphy.

In the Grays Harbor area the upper Miocene strata have a maximum thickness of 5,400 feet. In the Cape Elizabeth section north of the mouth of Queniult River the sandstones and shales are 3,000 feet in thickness while in southwestern Clallam County similar deposits are 1,500 feet thick. Detailed sections in these areas are included in the discussion of each district. In the Grays Harbor area the basal portion of the section is largely composed of shale or sandy shale, while the upper part consists of sandstones and conglomerates. The basal beds in the Queniult River section are chiefly brown shaly sandstones while the upper beds consist of alternating belts of conglomerates and sandstones containing large fragments of carbonized wood. In the Quillayute area the basal beds are conglomeratic and the upper strata more sandy or shaly.

Fauna

In the Grays Harbor area there is very little variation in the general character of the fauna from the base to the top of the formation. The basal beds were deposited in somewhat deeper water and contain some species which are absent from the shallow water deposits near the top. The deposits outcropping north of the mouth of Queniult River may be slightly younger than those to the south in southern Grays Harbor County. The same may be said for the beds at the junction of Soleduck and Bogachiel rivers in southwestern Clallam County.

The term Yoldia strigata Zone is applied to the faunas occurring within the upper Miocene beds of the Grays Harbor

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region. In other words but one faunal horizon is recognized within the Montesano formation. The following species are most common to this zone: *Arca trilineata* Conrad, *Cardium meekianum* Gabb, *Macoma astori* Dall, *Mulinia alta* Weaver, *Mulinea undulifera* (Weaver), *Pecten coosensis* Schumard, *Solen sicarius* Gould, *Yoldia strigata* Dall, *Argobuccinum cammani* Dall, *Chrysodomus imperialis* Dall, *Phalium aequisulcatum* Dall, *Sinum scopulosum* Conrad and *Scutella gabbi* Remond. All the species occurring in this zone are marine types.

The following table includes a list of the species known to occur within the state and the different localities where they have been found:

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UPPER MIOCENE.*

LIST OF SPECIES	30	46	52	60	61	68	93	94	96	99	100	101	111
PELECYPODA													
1 Arca trilineata Conrad		*		*		*							
2 Cardium corbis Martyn						*							
3 Cardium coosensis Dall										*			
4 Cardium meekianum Gabb													*
5 Chione securis Shumard	*		*	*		*				*			*
6 Chione bisculpta Dall						*				*			
7 Chione chehalisensis Weaver						*							
8 Chione montesanoensis Weaver						*							
9 Cryptomya oregonensis Dall						*							
10 Cryptomya washingtonensis Weaver						*							
11 Diplodonta parilis Conrad		*		*	*	*			*				
12 Glycimeris gabbi Dall						*							
13 Leda chehalisensis Weaver													
14 Leda sp.					*								
15 Macoma secta Conrad						*							
16 Macoma nasuta Conrad					*	*							
17 Macoma montesanoensis Weaver					*	*							
18 Macoma calcarea Gmel	*												
19 Macoma piercei Arnold						*							
20 Mactra coalingensis Arnold		*		*		*		*		*			*
21 Modiolus directus Dall						*							
22 Mytilus condoni Dall					*								
23 Mytilus mathewsoni Gabb						*							
24 Mulinea alta (Weaver)					*	*				*			
25 Mulinea undulifera (Weaver)						*							
26 Mulinea landesi (Weaver)					*	*							
27 Marcia oregonensis (Conrad)													
28 Nucula conradi Meek			*			*				*		*	*
29 Panope generosa (Gould)													
30 Phacoides acutilineatus (Conrad)													*
31 Phacoides annulatus (Reeve)			*										
32 Pecten coosensis Shumard													
33 Pecten propatulus Conrad													
34 Solen sicarius Gould		*			*	*							
35 Solen conradi Dall		*											
36 Spisula albaria (Conrad)		*	*	*		*			*				
37 Spisula catilliformis (Conrad)													
38 Semele montesanoensis Weaver						*							
39 Thracia trapezoidea Conrad						*							
40 Thracia oregonensis Dall		*											
41 Tellina kincaidii Weaver						*							
42 Tellina merriami Weaver						*							
43 Tapes stayleyi Gabb		*			*	*							
44 Venericardia castori Dall							*						
45 Yoldia submontereyensis Arnold	*												
46 Yoldia strigata Dall		*		*									*
GASTEROPODA													
47 Argobuccinum cammani Dall													
48 Argobuccinum coosensis Dall													
49 Bathytoma gabbiana Dall						*							
50 Bathytoma bogachielli Reagan						*							*
51 Buccinum bogachielli Reagan						*							*
52 Calyptraea filosa (Gabb)						*							
53 Chrysodomus imperialis Dall						*							*
54 Chrysodomus bairdi Dall						*							
55 Chrysodomus giganticus Reagan													*
56 Columbella gauspata Dall		*											
57 Crepidula princeps Conrad		*		*		*							
58 Calliostoma stantoni Arnold													
59 Cymatium pacificum Dall						*							
60 Eulima smithi Reagan													*
61 Eulima washingtonensis Reagan													*
62 Epitonium rugiferum Dall						*							
63 Fusinus montesanoensis Weaver						*							
64 Gyrineum sylviaensis Weaver						*							
65 Gyrineum mediorre var corbiculatum Dall						*							
66 Liomesus sulcatus Dall						*							
67 Nassa andersoni Weaver				*									
68 Nassa arnoldi Anderson	*	*											
69 Neptunia maxfieldi Reagan						*							*
70 Olivella pedroana Conrad				*									*
71 Polynices galianoi Dall						*							
72 Polynices clausa B. & S.	*	*	*	*		*							*
73 Phalium aequisulcatum Dall						*		*					
74 Ranella marshalli Reagan													*
75 Sinum scopulosum Conrad		*											
76 Thais etchegoinensis Arnold		*											
77 Turris coosensis Dall													
78 Turris perversa Gabb													
79 Scutella gabbii Remond						*		*					
80 Dentalium conradi Dall													
81 Teredo sp.													

* From Tertiary Faunal Horizons of Western Washington, University of Washington Publications in Geology, Vol. I, No. 1, pp. 32-33.

UPPER MIOCENE—CONTINUED.

	112	115	117	118	119	120	121	123	124	125	126	132a	132	140	141	142	144	145	146	147	148	151	152	163	174
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81																									

UPPER MIOCENE—CONCLUDED.

	LIST OF SPECIES	181	182	185	189	193	194	197	200	201	202	209	210	211	215
	PELECYPODA														
1	Arca trilineata Conrad				*										
2	Cardium corbis Martyn						*		*						
3	Cardium coosensis Dall														
4	Cardium meekianum Gabb														
5	Chione securis Shumard				*		*		*						
6	Chione bisculpta Dall						*								
7	Chione chehalisensis Weaver														
8	Chione montesanoensis Weaver														
9	Cryptomya oregonensis Dall														
10	Cryptomya washingtonensis Weaver														
11	Diplodonta parilis Conrad			*			*								
12	Glycimeris gabbi Dall														
13	Leda chehalisensis Weaver														*
14	Leda sp.														
15	Macoma secta Conrad														
16	Macoma nasuta Conrad														
17	Macoma montesanoensis Weaver														
18	Macoma calcarea Gmel														*
19	Macoma piercei Arnold						*								
20	Mactra coalingensis Arnold						*								
21	Modiolus directus Dall														
22	Mytilus condoni Dall														
23	Mytilus mathewsoni Gabb							*							
24	Mulinea alta (Weaver)	*					*								
25	Mulinea undulifera (Weaver)														
26	Mulinea landesi (Weaver)														
27	Marcia oregonensis (Conrad)														
28	Nucula conradi Meek								*				*		
29	Panope generosa (Gould)				*			*							
30	Phacoides acutilineatus (Conrad)														
31	Phacoides annulatus (Reeve)														
32	Pecten coosensis Shumard									*					
33	Pecten propatulus Conrad	*				*									
34	Solen sicarius Gould														
35	Solen conradi Dall				*				*						
36	Spisula albaria (Conrad)	*			*		*								
37	Spisula catilliformis (Conrad)				*										
38	Semele montesanoensis Weaver														
39	Thracia trapezoidea Conrad													*	*
40	Thracia oregonensis Dall														
41	Tellina kincaidii Weaver														
42	Tellina merriami Weaver														
43	Tapes staleyi Gabb														
44	Venericardia castori Dall											*			*
45	Yoldia submontereyensis Arnold										*				
46	Yoldia strigata Dall				*										
	GASTEROPODA														
47	Argobuccinum cammani Dall											*	*	*	
48	Argobuccinum coosensis Dall														
49	Bathytoma gabbiana Dall														
50	Bathytoma bogachielli Reagan						*								
51	Buccinium bogachielli Reagan						*								
52	Calyptraea filosa (Gabb)														
53	Chrysodomus imperialis Dall						*								
54	Chrysodomus bairdi Dall														
55	Chrysodomus giganticus Reagan														
56	Columbella gauspata Dall														
57	Crepidula princeps Conrad				*		*								
58	Calliostoma stantoni Arnold	*													
59	Cymatium pacificum Dall														
60	Eulima smithi Reagan														
61	Eulima washingtonensis Reagan														
62	Epitonium rugiferum Dall														
63	Fusinus montesanoensis Weaver														
64	Gyrineum sylvinensis Weaver														
65	Gyrineum mediocre var corbiculatum Dall						*								
66	Liomesus sulcatus Dall														
67	Nassa andersoni Weaver														
68	Nassa arnoldi Anderson														
69	Neptunia maxfieldi Reagan														
70	Olivella pedroana Conrad														
71	Polynices galianoi Dall						*								
72	Polynices clausa B. & S.				*		*		*						
73	Phalium aequisulcatum Dall						*								
74	Ranella marshalli Reagan														
75	Sinum scopulosum Conrad				*										
76	Thais etchegoinensis Arnold														
77	Turris coosensis Dall														*
78	Turris perversa Gabb	*													
79	Scutella gabbii Remond														
80	Dentalium conradi Dall														*
81	Teredo sp.														

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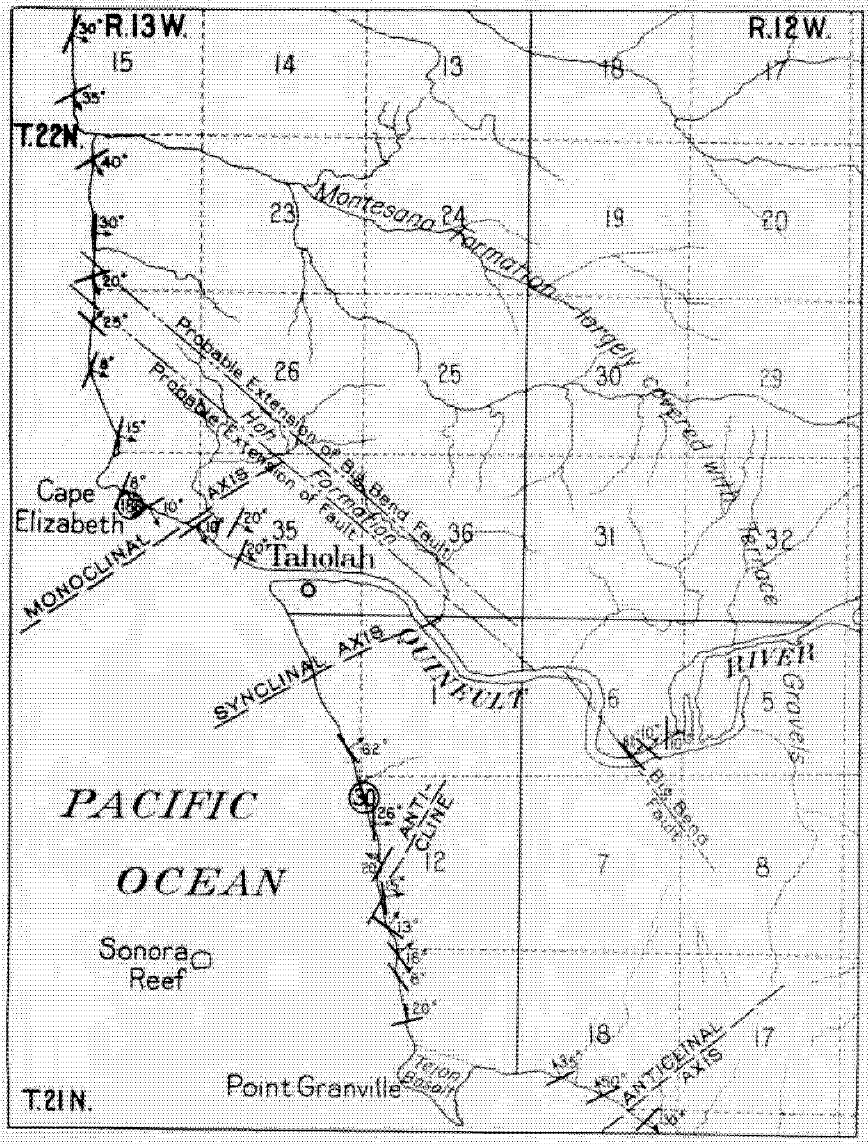

Geologic and Structural Map at Mouth of Queniult River.

GRAYS HARBOR AREA.

Geographic Distribution. The upper Miocene formation in the Grays Harbor region lies almost entirely north of Chehalis River and within the drainage basin of Satsop, Wynoochee, Wishkah, Hoquiam and Humptulips rivers. From the Humptulips westward to the ocean all of the bedrock formations are covered with Pleistocene fluviatile deposits consisting of sands, gravels, and clays. The older Montesano formation, however, reappears on the Queniult Indian Reservation north of Point Grenville and in the vicinity of Cape Elizabeth.

The south contact with the Oligocene is designated upon Plate III. Its position is only approximate and has been determined partly on a palaeontological and partly upon a lithologic basis. The eastern contact with the older Tejon basalts is very indefinite. The bedrock formations are in most places heavily covered with deposits of glacial drift. Occasionally small exposures of basalt or sandstone occur and it is by tracing the approximate lines between these that the contact on the map has been determined.

The north contact with the Tejon basalt has been definitely determined at certain points as in the canyons of Wynoochee, Wishkah, and Humptulips rivers. Between these points its approximate position has been determined and located by an examination of the exposures in the smaller creeks. The contact presumably extends northwesterly and crosses Queniult River near the basalt exposures in the Burnt Hills in Section 12, Township 22 North, Range 11 West. The western contact has been drawn only approximately and west of it there is no means of determining what the underlying formation may be.

Character of Outcrops. The surface topography of the area just outlined is rolling and heavily veneered over with rusty colored gravels and sands. This plain has been dissected by the Satsop, Wynoochee, Wishkah and Humptulips rivers. Along the banks of these streams the bed rock is in many places exposed. The smaller creeks sometimes cut into bed rock but more often only into the fluviatile sands and gravels. The original pre-Pleistocene surface topography was undulating. The deeper depressions were filled with thicker accumulations of Pleistocene gravels and sands. Where the present rivers cut across these areas, as a rule, bed rock has not as yet been intersected. Where the rivers have cut down into the older formations, high bluffs are sometimes present. Occasionally the rivers flow in deep gorges as in the upper part of the Wynoochee Valley. This is especially true farther north in the basaltic areas.

Steeper bluffs are situated along the south side of Chehalis River and excellent exposures of the formation may be seen in the railway cuts and excavations. In Township 18, North, Ranges 7 and 6 West, very little overburden of gravel and sand is present. The typical coarse sandstones of the Montesano formations are well exhibited. A large part of the area has been logged off and numerous rock cuts have been made. This is also true where the smaller streams emptying into Satsop River have cut down into bed rock. Almost continuous outcrops may be seen in the logging railroad cuts along Sylvia Creek north of Montesano. These exposures rapidly pass into soil after having been exposed for some time. On the west and middle branches of Wishkah River, good outcrops occur in the banks of the streams from the basalt contact on the north southward to Grand Forks. Often these appear only a few feet above the bed of the streams and sometimes are separated by gravel areas so that the Montesano formation does not appear at all. Similar exposures occur on Humptulips River from the basalt contact in Section 35, Township 21 North, Range 9 West, westerly to the junction with the west branch of the same river. From that point to Humptulips City the area through which the Humptulips flows is flat and gravel-covered and no bedrock bluffs occur. One mile south of Humptulips City rock exposures reappear but from that point to its mouth they are deeply covered with gravels and sands of Pleistocene age.

Beginning at a point three miles east of Aberdeen the Montesano formation outcrops almost continuously to Hoquiam and

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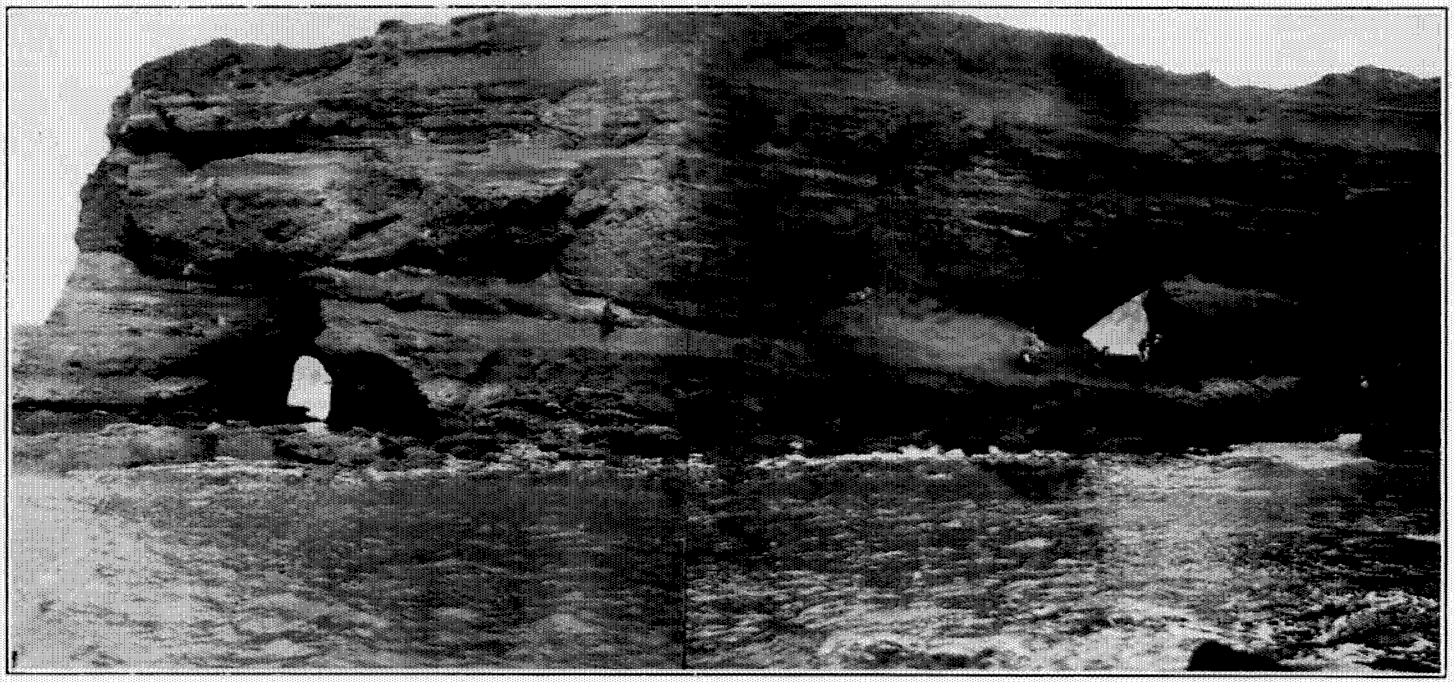

Upper Miocene Formation as Exposed at Cape Elizabeth, Grays Harbor County.

DNR-00005211

beyond for some distance. Both the Wishkah and Hoquiam rivers have cut through it. About three miles north of this belt the country merges into an undulating flat-topped plain heavily covered with gravel. Very few bedrock exposures occur in this region. On the south side of Chehalis River from Cospomolis to West Aberdeen and for three miles south, the massive sandstones of the Montesano formation are conspicuous. Farther south the country is heavily timbered and covered with gravel and sand.

Lithology. The upper Miocene deposits of Washington are largely composed of materials deposited under conditions ranging from shallow water to that of moderate depth. Coarse grained brownish gray sandstones prevail. Often these become gritty and locally pass into a fine conglomerate. Cross-bedding is characteristic of the series. The shales, when present, are generally bedded and often contain intercalated layers of sandstone. Occasionally hard nodules are developed in the shales. The shales are fine-grained and of a bluish gray color. Typical examples of the sandstones may be seen in the street cuts of Hoquiam and Aberdeen, on Sylvia Creek back of Montesano and on Vance Creek between Satsop and Elma. The shales which are most prominent in the lower portion of the series are best developed on the upper courses of Wishkah River. They also occur on the Humptulips River above the junction of the west and east forks, on the latter.

Geologic Structure. The prevailing structure which the strata of the Montesano formation assume in this area consists, in common with that south of Grays Harbor, of a series of northwest to southeast anticlinal and synclinal folds.

Detailed traverses were run along the Humptulips, Wishkah and Wynoochee rivers. The strata were measured and the strikes and dips recorded. The positions of the anticlinal and synclinal axes have been designated upon Plate III.

At Humptulips City in Section 7, Township 20 North, Range 10 West, an anticline crosses the river, trending North 60° West. On the north limb the shales are dipping at angles

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ranging from 60° to 78° to the northeast. On the south limb the dip is 35° to the southwest. How far this anticline extends to the northwest or southeast cannot at present be determined as all bedrock exposures are obscured by the overburden of Pleistocene gravels and sands.

In Sections 1, 2, and 3 of the same township and range an anticline trends nearly parallel to the river for two miles and bears off to the southeast. Observations show it to cut from one bend of the river to another. Rock exposures are almost continuous and observations taken on the north limb of the anticline show it to dip from 42° to 82° to the north and northeast. On the south limb the dip varies from 35° to 85° to the southeast. On both flanks the dip varies from point to point along the trend of the anticline. About half way between the two anticlines just described a synclinal trough is assumed to exist. No exposures are present in this region and its exact position and extent cannot be determined.

In Section 20, Township 20 North, Range 8 West an anticline crosses Wishkah River, trending North 70° West. The north flank is pitching to the northeast at an angle ranging from 30° to 60°. The south limb dips 54° to the southwest towards the axis of a parallel syncline passing through the extreme northeast corner of Section 31, same township and range. South from this synclinal axis for a distance of three miles, the strata are dipping to the northeast at angles ranging from 17° to 14°. In Section 12, Township 19 North, Range 9 West an anticline again crosses Wishkah River trending in the same direction. South from it the gravels and sands become thicker and deeper and bed rock exposures in the river banks are not so common.

The southeastern extension of the last anticline described, crosses Wynoochee River in Section 28, Township 19 North, Range 8 West. The intervening area between the Wynoochee and Wishkah rivers is largely devoid of bed rock outcrops so that the underlying structure cannot be definitely determined. To the east of Wynoochee River the outwash from the Puget

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Sound glacial field covers the region so thickly that no attempt has been made to work out definite structure. In Township 18 North, Range 7 West, exposures are fairly abundant and the strata are dipping at low angles ranging from 5° to 15° to the north. On the east fork of Satsop River in Section 5, Township 18 North, Range 5 West, the strike is North 75° West and the dip 20° southwest. It is possible that a shallow synclinal trough trends northwest to southeast between these two localities.

Stratigraphy. The following stratigraphic section has been measured from exposures occurring along the middle fork of Wishkah river. The base of this section lies in Section 14, Township 19 North, Range 9 West.

WISHKAH RIVER TRAVERSE.

	Feet
Bluish gray shale	500
Gray shaly sandstone (Fossil Loc. 117-119)	350
Brown gray sandstone—concretionary	200
Bluish gray, shaly sandstone	550
Massive gray sandstone (Fossil Loc. 121)	100
Gray shaly sandstone	450
Blue gray laminated sandy shale	100
Gray sandy shale	50
Sandstone with nodules	60
Sandstone (Fossil Loc. 123)	200
Gray sandstone	1300
Gray sandy shale (Fossil Loc. 125)	300
Sandstone	900
Conglomerate	400
Base of section at station 269.	
Total	5460

To the northwest in the lower valley of Queniult River the upper Miocene strata have been folded into a shallow synclinal trough which pitches inland in a northeasterly direction. Minor folds exist on the flanks of this syncline. In Section 12, Township 21 North, Range 13 West, a small local syncline and anticline have been formed whose axes trend northeast and southwest. In Section 34, Township 22 North, Range 13 West, a small fold in the nature of a monocline passes from the shore south of Cape Elizabeth in a northeasterly direction. A fault exists trending from a point on the coast about one mile

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north of the Cape southeasterly to the big bend in Queniult River in the southeast quarter of Section 6, Township 21 North, Range 12 West. A block of the Hoh formation lies on the eastern side of the fault plane in contact with the upper Miocene strata. East of the Hoh fault block the Miocene gravels and sandstones again appear. The eastern portion of the Queniult Indian reservation affords no opportunities for determining the structural conditions of the upper Miocene strata.

Near the mouth of Queniult River the upper Miocene strata are well exposed. From a point about one mile north of Cape Elizabeth south to the mouth of the river a detailed stratigraphic section has been measured. The top of this section is located along the shore north of the mouth of the river and the base at the fault contact north of Cape Elizabeth. (Plates XXVI, XXVII, XXVIII and XXIX.)

DETAILED CROSS SECTION, UPPER MIOCENE, AT CAPE ELIZABETH.

Top	*Feet*
Shaly sandstone	2
Medium grained conglomerate	25
Sandy shale	2
Conglomerate	18
Shaly sandstone	7
Conglomerate	28
Sandstone with lenses of conglomerate	14
Nodular sandstone	11
Medium grained conglomerate	5
Hard sandstone	3
Conglomerate with large pebbles	18
Shale	3
Concretionary shale	30
Medium grained conglomerate	12
Shale	30
Coarse conglomerate	8
Sandy shale	15
Conglomerate	10
Sandy shale	15
Loosely consolidated conglomerate	20
Sandy shale	15
Medium grained conglomerate	10
Shaly sandstone with nodules	12
Fine conglomerate	3
Sandy shale	9
Conglomerate	14
Sandstone	6
Conglomerate	2
Sandy shale and clay nodules	3
Conglomerate with a few angular pebbles	35
Sandy shale	10

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Top	*Feet*
Medium grained conglomerate	2
Shaly sandstone	2
Conglomerate with fine layers of sandstone	13
Shaly sandstone	14
Conglomerate	10
Shaly Sandstone	6
Fine conglomerate	4
Pebbly sandstone	10
Laminated sandstone	14
Fine conglomerate	10
Soft shaly sandstone	12
Conglomerates	23
Shaly sandstone	12
Medium grained conglomerate containing hard clay nodules	11
Massive shaly sandstone	26
Intercalated sandstone and conglomerate	15
Shale	16
Sandstone	6
Massive sandy shale	12
Medium grained conglomerate	11
Massive medium grained sandstone containing hard nodules	10
Coarse conglomerate	10
Nodular shale	4
Massive medium grained sandy shale occurring at the keyhole	41
Sandy shale	2
Medium grained conglomerate	2
Medium grained shaly sandstone	7
Shaly sandstone	4
Fine grained shaly sandstone	11
Coarse grained sandstone	15
Sandy shale	3
Fine conglomerate	2
Shaly sandstone	2
Shaly sandstone, containing pebbles	6
Conglomerate	15
Sandstone	3
Fine grained conglomerate	6
Shale	1
Sandstone with pebbles	3
Shaly sandstone	1
Sandstone and conglomerate	9
Sandstone	3
Conglomerate	3
Shale	2
Sandy conglomerate	25
Conglomerate	3
Conglomerate and sandstone	12
Conglomerate	9
Sandstone	12
Conglomerate	1
Sandstone	1
Shaly sandstones	12
Sandstone	5
Sandy shale with hard, nodular layers	10
Banded sandy shale	15
Sandy shale	15
Base of section.	
Total	936

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QUILLAYUTE AREA.

Geographic Distribution. Upper Miocene strata outcrop at several localities in the vicinity of the junction of the Bogachiel and Soleduck rivers in southwestern Clallam County in the central portion of Township 28 North, Range 14 West. The exact contact boundaries can be only approximately determined as the outcrops are few in number. The greater part of the country is covered with soil and undergrowth. It is probable that only one area exists and its approximate contacts have been indicated by broken lines on Map A, Plate IV.

Character of Outcrops. The surface outcrops are confined chiefly to low bluffs on the banks of Bogachiel and Soleduck rivers. On the Soleduck River in Section 16, Township 28 North, Range 14 West, outcrops of sandy shale and shaly sandstone occur which in places are fossiliferous. These exposures are located on the left bank of the stream in cliffs about twelve feet in height and extend for a distance of 500 feet. They are covered unconformably with river gravels and boulders. A number of similar exposures outcrop on Bogachiel River in Sections 27, 28 and 29, same township and range. They occur in the form of low bluffs along the banks of the river and contain marine fossil molluscan remains.

Lithology. The upper Miocene strata in this region are entirely of sedimentary origin and were deposited in a marine embayment. They consist of sandstones, shaly sandstones and sandy shales. The sandstone is very compact, medium grained and when unweathered of light gray color. It is hard and resistant to weathering. The shales are of a brownish gray color, somewhat massive and weather in angular fragments. They are not hard, but rather tough. Occasional gravelly or gritty layers or lenses are interbedded. The thickness has not been exactly determined but approximates at least 1,500 feet.

The strata assume very low dips so that wherever exposures may be seen along the river banks not over ten or twelve feet of a section can be measured at any one place. The materials do not vary in the section at any particular locality, consequently no detailed sections of the formation have been made.

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Geologic Structure. The upper Miocene as represented in this region rests unconformably upon the Hoh formation. Observations taken upon outcrops along Bogachiel River show the prevailing strike to be approximately North 70° West and the dip 10° to 15° to the northeast. Observations taken on Soleduck River indicate a similar strike with a very low dip to the south. Apparently these strata have been folded so as to constitute a shallow syncline with an axis trending a little north of west. The area now exposed presumably represents only the residual of a formerly much more extensive deposit. It is possible that small patches may exist farther to the north which so far have escaped detection. The country is low and flat and outcrops are few.

These sediments were deposited in a basin or inlet from the ocean which was developed at some time after the middle Miocene mountain making movements had taken place. The seas apparently were not deep at any time so only shallow water species of molluscs are found. The climate as interpreted by the types of life present was colder than during the lower Miocene. It was probably very similar to that of the present time.

Fauna. The fauna consists of 20 species of Pelecypods and Gasterpods. Nearly all of these were collected from locality numbers 111, 112, 113, 114 and 115. The largest collection came from the bluffs on the south side of Bogachiel River in Section 28, Township 28 North, Range 14 West, where a small creek enters the river from the south. Along this bluff is the old abandoned channel of Maxwell Creek. The exposures for some distance up Maxfield Creek are not a part of the upper Miocene but rather of the Hoh formation. The following fauna were collected from this locality.

PELECYPODA

Cardium meekianum Gabb
Chione securis Shum
Phacoides acutilineatus Conrad
Yoldia strigata Dall
Nucula c. f. *conradi* Meek
Spisula albaria Conrad
Mactra coalingensis Arnold
Arca trilineata Conrad
Spisula catiliformis Conrad

GASTEROPODA

Buccinum bogachielli Reagan
Chrysodomus giganticus Reagan
Chrysodomus imperialis Dall
Eulima washingtoniana Reagan
Eulima smithi Reagan
Natica clausa B and S
Ranella marshalli Reagan
Polynices lewisii
Olivella pedroana Conrad
Polynices galianoi Dall

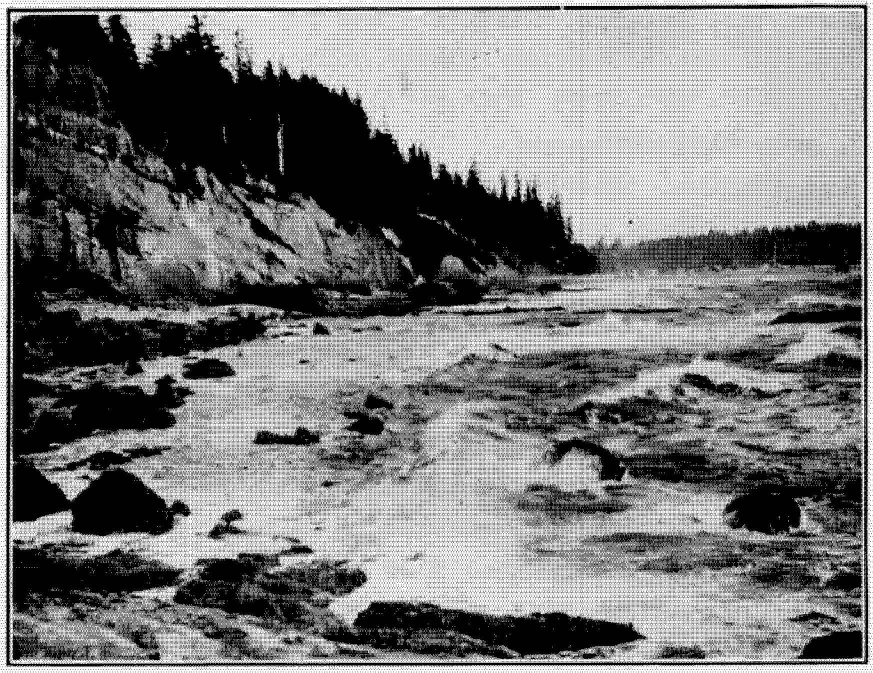

Figure A.—Upper Miocene Sandstones Looking South From Cape Elizabeth Toward Queniult River.

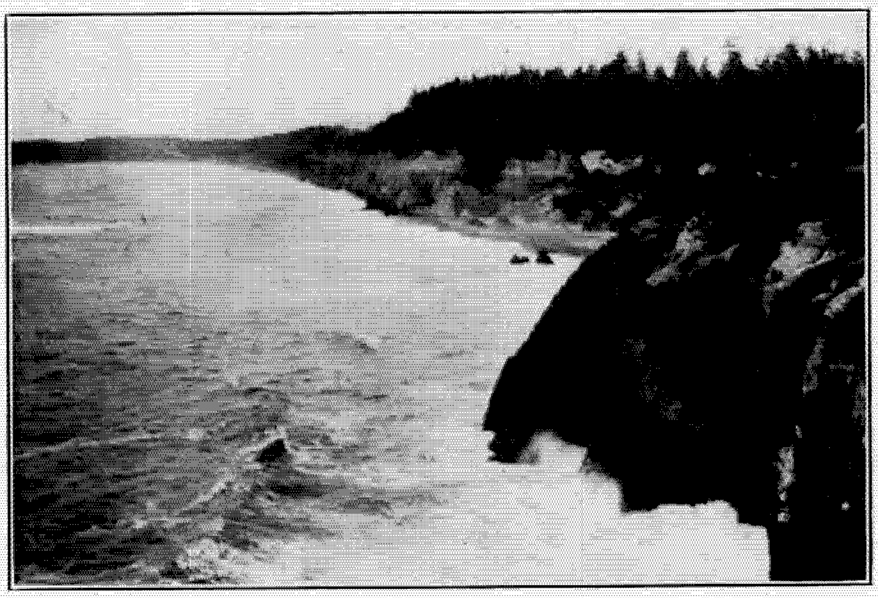

Figure B.—Upper Miocene Shale Looking North From Point Grenville Towards Queniult River.

Of these the most common species are *Spisula albaria*, *Spisula catiliformis*, *Chrysodomus imperalis*, *Chione securis*, *Chione meekianum* and *Yoldia strigata*.

SNOQUALMIE GRANODIORITE.

Outcrops of granodiorite are exposed at the surface at many points in the western foothills of the Cascades. They were in part formed at or near the close of the Jurassic period and in part during the later portion of the Miocene epoch. The former have been described as the Index granodiorites. The latter are exposed in eastern King County in the valley of Snoqualmie River. The hills between the north and south forks of Snoqualmie River are largely composed of granodiorites which are intrusive into a series of quartzites and schists of presumable early Mesozoic age. Similar rocks exist to the south of the south fork of Snoqualmie River as far as the crest of the divide with Cedar River. Along the wall of Cedar River Valley the granodiorites are capped by flows of andesite and deposits of tuff of enormous thickness. Exposures of granodiorite occur almost continuously from North Bend easterly to the crest of the Cascade Mountains. Near the headwaters of Snoqualmie and Cedar rivers the granodiorites have been studied and mapped by the U. S. Geological Survey and are designated in the Snoqualmie Folio as the Snoqualmie granodiorite.* They are believed to be of late Miocene age. On the basis of studies made in that region and on the fact that areal exposures of the same formation can be traced continuously from the border of the Snoqualmie Folio westerly to the junction of the south and middle forks of Snoqualmie River, the granodiorites of this region are regarded as of upper Miocene age and a part of the Snoqualmie granodiorite.

A field examination of the granodiorite shows a considerable variation in texture and mineral composition. Basic secretions of badly altered hornblende and biotite are common. Aplitic intrusions are characteristic near the contact of the bathylith

* Smith, G. O. and Calkins, F. C., Snoqualmie Folio, U. S. Geological Survey, No. 139. 1906.

with the overlying schists and quartzites. Away from the contact the rock possesses a somewhat uniform character. It is medium grained and composed of biotite and hornblende with plagioclase and minor amounts of quartz. Under the microscope the rock is seen to be largely composed of plagioclase of the oligoclase variety and biotite. Orthoclase is present in subordinate amounts. Quartz is clear and glassy and forms on the average about 10% of the total content of the rock. Green hornblende is fairly abundant but subordinate in amount to biotite. Small prisms of apatite and occasional crystals of titanite are often present. Except when unduly exposed to weathering the rock as a whole is comparatively fresh.

ENUMCLAW VOLCANIC SERIES.

Geographic Distribution.

In eastern Snohomish, King and Pierce counties there are extensive accumulations of lava and tuff resting unconformably upon older quartzites, schists and granodiorites, as well as the Eocene and Oligocene sedimentary formations of the eastern portion of the Puget Sound Basin. They account in part for the somewhat steep escarpments along the western foothills of the Cascade Mountains. In King County the estuarine Eocene deposits outcrop in nearly all the river and creek canyons as far east as the western escarpment of the Cascades where they disappear beneath the lavas and tuffs. This contact extends from Fall City southerly along Raging River to Barneston and thence along the Northern Pacific Railway to Enumclaw and Carbon River. Residual patches of lava occur in many places to the west of the contact. The northern boundary of this volcanic area extends from the town of Snoqualmie southeasterly along the east wall of Snoqualmie Valley to the foot of Rattlesnake Ledge near the town of Cedar Falls and thence up the northern side of Cedar River Valley. Similar lavas are exposed on the south side of Skykomish Valley in Snohomish County as far as the eastern margin of the Puget Sound Basin. In southern Pierce and in Lewis counties the lavas are exposed to the southwest and are sometimes difficult to separate from the Eocene volcanic flows especially in those areas where glacial deposits are extensive.

Lithology.

Rock exposures are often exhibited in the rugged and steep cliffs along the canyons of the rivers and creeks flowing westerly through the Cascades. The basal portion of the formation may be seen in the small creeks one mile south of North Bend. Granodiorites and quartzites form the outcrops up to elevations of approximately 800 feet. Above the granodiorites are flows of badly altered basic andesite. The lower flows are somewhat porphyritic although the crystals are usually small. A microscopic examination of the fresher material shows the presence of basic labradorite together with augite and minor amounts of hornblende. The higher flows exposed in the ridge occur on the top of Rattlesnake Ledge and are pitching to the southwest at an angle of 30°. They range in character from a vesicular rock to a massive agglomerate. The several phases are interbedded as bands of varying thickness. Excellent outcrops of the lavas may be observed in the canyon of Cedar River below Cedar Lake. They are also pitching to the southwest and Cedar River has cut down diagonally across the strike. At the site of the new Cedar River dam excavations have been made and the detailed character of the rocks may be studied. The rocks as exposed consist of fine grained andesites intercalated with distinctly bedded fine grained bluish gray volcanic ash. The ash bands vary in coarseness of grain and often contain small pieces of pumice. Thick bands of tuff are present which contain angular fragments of pumice, vesicular lava, fine grained, dense glassy andesite together with fragments of carbonized wood. In the bedded tuffs or clays fossil leaves are in places abundant. In the vicinity of Enumclaw the lavas are in the nature of acidic basalts. They occur intercalated with light colored tuffs which are resting nearly horizontal and possess a thickness of at least 1,000 feet.

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Detailed examinations were not undertaken on the western slopes of the Cascades but from such observations as were made along the canyons of White and Green rivers the lavas and tuffs occur as gentle folds all of which are trending northwest and southeast. Along the western margin of the lava escarpment there is some evidence of complex and repeated faulting parallel to the contact. The differential resistance to erosion of the lavas as compared with the softer Eocene sedimentaries is in part responsible for the abrupt and somewhat linear termination of the western border of the foothills of the Cascades.

On the south side of the ridge extending from North Bend to Newcastle numerous intrusive dikes occur cutting the Eocene sedimentaries. This is especially true between Raging River and Issaquah Creek. It is possible that these dikes may have been feeders to lava flows in that region which have since been removed by erosion. The area is thickly covered with deposits of glacial drift and it may be that residuals of lava are present which have not as yet been observed because of the drift.

Correlation.

The contact between the lava series and the underlying granodiorites in Snoqualmie Valley is one of unconformity rather than intrusion. The same condition exists with respect to the Eocene sedimentaries and the lavas at Durham, Kanaskat and Enumclaw. The lava series as exposed at the above localities when traced easterly, directly connects with the Keechelus volcanic series, as exposed along the Cascade divide in the Snoqualmie Folio. The lavas as mapped in this folio have been described by Dr. G. O. Smith as of upper Miocene age and were regarded by him as older than the Snoqualmie granodiorite. The granodiorite is described as being intrusive into at least a part of the Keechelus formation.

The lavas referred to in this report as occurring along the western border of the Cascade Mountains are described as the Enumclaw volcanic series. It is possible that they may be in part the equivalent of the Keechelus formation. The granodiorites south of North Bend are not intrusive into the Enumclaw volcanics but the lavas as exposed there may be the equivalent of the upper portion of the Keechelus formation as exposed near the summit of the Cascades. There does not seem to be any evidence at present to warrant a direct correlation of the Enumclaw volcanic series with the Keechelus formation although they are probably in part equivalent.

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CHAPTER VI.

PLEISTOCENE FORMATIONS.

GENERAL STATEMENT.

Deposits of Pleistocene age are well developed in western Washington. They consist of glacial drift, fossiliferous marine sands, clays and gravels, old stream gravels and sands, recent stream alluvial deposits, and sand-bar and tidal flat deposits. For purposes of mapping, as well as discussion, these deposits have been divided into two broad groups, namely, glacial morainic deposits and terrace deposits.

GLACIAL DEPOSITS.

GENERAL STATEMENT.

In this report no attempt has been made to study in detail the glacial deposits of western Washington except in a general way to note their distribution. Careful attention has been given to the glacial question by Bailey Willis* and J. H. Bretz**. The generalization here set forth is largely a summary of their work.

On the geologic map accompanying this report glacial deposits have been mapped only when it was impossible to determine the probable nature of the underlying formations. (Plates II, III and IV.) The contact lines as drawn to limit the boundaries of the drift in reality represent the boundaries between those areas which are covered with drift where the underlying bedrock is unknown and those drift covered areas where the underlying formations are known.

GEOGRAPHIC DISTRIBUTION.

Deposits of glacial origin occupy a large part of the Puget Sound Basin, the north and south borders of the Olympic Peninsula and the north portion of the Grays Harbor region. Out-

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* Tacoma Folio No. 54, U. S. Geological Survey 1896.
** Bulletin No. 8, Washington Geological Survey, 1913.

wash gravels which are to be regarded as of glacial origin extend into Grays Harbor, Thurston and Lewis counties. Local morainic deposits may be found in the San Juan Islands and in the foothills of the Cascade Mountains. Deposits formed by alpine glaciation are common in the higher elevations of both the Cascade and Olympic mountains. Small alpine glaciers are in existence today in both of these mountain ranges at the headwaters of the larger stream valleys and on the slopes of the higher mountain peaks.

CHARACTER OF PLEISTOCENE GLACIATION IN WESTERN WASHINGTON.

Early in the Pleistocene the Cascade Mountains had been elevated into their present position. The Juan de Fuca trough had been brought to sea level or possibly below. A series of deep channels having a north-south direction, had been developed in the Puget Sound downfold. Possibly these stream valleys may have been depressed sufficiently to allow the marine waters to enter, although we have no direct evidence that such was the case. The climate had been gradually growing colder during the Tertiary. Precipitation probably increased. Abnormal precipitation in the form of snow allowed great snow fields to accumulate both in the Cascade Mountains and in British Columbia. These ice streams increased in size and flowed down the early Pleistocene stream valleys and coalesced in the great Puget Sound-Strait of Georgia plain into which they emptied. Ultimately this great plain or basin was filled so as to constitute one great field of ice. Later the ice retreated and left behind various types of glacial deposits brought down from the mountains by the glaciers. These deposits have been designated as the Admiralty till. The time interval during which the Admiralty glacier occupied the Sound region has been termed the Admiralty epoch.

At the close of the Admiralty Epoch the great ice sheet began to retreat. It finally disappeared leaving the entire Puget Sound region covered with detritus. During this time the region was being elevated, perhaps to 1,000 feet. Stream erosion became active and great valleys were cut down into the deposits

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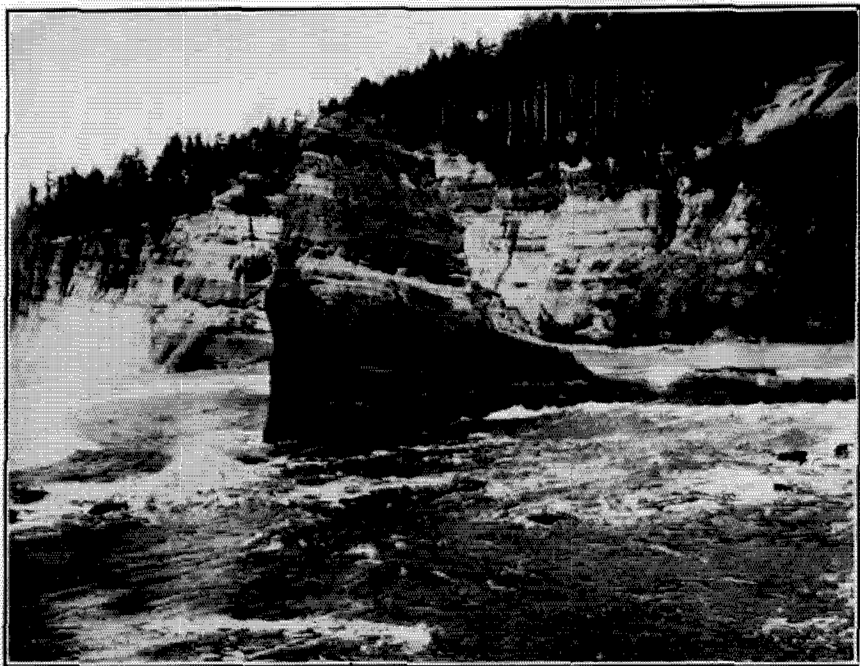

FIGURE A.—Upper Miocene Formations as Exposed Along Beach North of Cape Elizabeth.

FIGURE B.—Point Grenville, Showing Eocene Basalts on Beach at Low Tide.

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of the Admiralty glaciation. The time interval involved in the retreat of the ice, in uplift and extensive erosion and aggradation is known as the Puyallup interglacial epoch. All of the main stream channels formed during this time are thought to have had a predominant north-south trend.

Towards the close of the Puyallup Epoch conditions again allowed the development of great ice streams in the valleys of British Columbia and the Cascade Mountains of Washington. They advanced and the Puget Sound basin was again filled with ice. The margins of this great ice field even crowded up into the stream valleys issuing from the Olympic Mountains. To the south the margin of the ice advanced to the already subdued core of the Black Hills upwarp. Two great lobes were developed. One of these passed to the south and east of the Black Hills and the other swung around to the west through a low gap extending towards Matlock. Beyond the limits of the terminal moraine at the front margin of the glacier there are spread out great outwash gravel plains. These extend from Mason County westerly to Grays Harbor and from the eastern lobe over the plains of Thurston County into northern Lewis County at Centralia. During this maximum advance of the ice the front margin of the glacier oscillated back and forth so as locally to allow the morainic material to over-ride the outwash gravels.

This field of ice is considered to have extended as a solid mass from the Cascades to the Olympics. As it began to retreat by the melting away of the front margin, a great pond of water accumulated which could not escape to the north because of the ice wall, nor to the south because of the rock and morainic barriers. In places streams were able to spill over the front retaining wall and cut out drainage channels, but not sufficiently to drain the lake. As the ice field gradually retreated to the north the lake became larger. It was bordered on the west by the Olympics, on the east by the Cascades, on the north by the ice front and on the south by the rock ridge. As the lake increased in size, streams from the Olympics and Cascades began to drain into it. Great deltas were developed on its margin. These gradually extended out into the lake. The sediments laid down were characterized by cross-bedding. Ultimately the ice retreated sufficiently to the north to allow the waters of the lake to drain to the ocean through the Strait of Juan de Fuca. The Strait of Juan de Fuca had itself been filled with ice during the maximum extent of glaciation. The present topographic features of the Sound owe their origin largely to the conditions which prevailed during Pleistocene glaciation. The time interval during which this last ice field advanced and retreated has been termed the Vashon glacial epoch.

It is thought that the Puget Sound basin had been lowered from its former elevated position to nearly its present elevation during the time of maximum Vashon glaciation. After the ice had entirely retreated the region is believed to have been submerged 250 feet more. Later it was again re-elevated to approximately its present position. The evidence for this is the occurence of elevated beaches containing marine shells.

The latest diastrophic movement consisted of a slight elevation of perhaps twenty feet above sea level so as to produce rock cut terraces and deposits of marine molluscan remains as may be seen at the entrance to the Bremerton Navy Yard and at Alki Point in Seattle. These marine deposits will be discussed under the marine phase of Terrace Deposits which is to follow.

TERRACE DEPOSITS.

GENERAL STATEMENT.

Under the general term, terrace deposits, for purposes of convenience in mapping, are included all deposits of Pleistocene age excepting those of definite glacial origin. More important among these are old fluviatile deposits of Pleistocene age, recent alluvial deposits, products of rock decay which are still in place, sand dunes, marine beach deposits, and tidal flat muds. These will be described in the order just referred to.

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FLUVIATILE DEPOSITS.

Under fluviatile deposits are included the sands, gravels and clays deposited by Pleistocene river channels at a time when the surface of the western portion of the state was much lower than at the present time. These deposits vary much in thickness as well as in character. They form extensive accumulations along the west and south margins of the Olympic peninsula, along the shores of Willapa and Shoalwater bays, in the Cowlitz Basin and in the counties bordering Columbia River. They record the shifting and meandering of numerous streams. After their deposition the entire western portion of Washington appears to have been uplifted and the present streams have carved their channels down through this earlier river wash and in places have cut into the underlying older Tertiary bedrock formations.

Along the western slope of the Olympic Mountins there is an uplifted plain extending from Cape Flattery southward to Grays Harbor. This belt averages twenty miles in width and extends up into the western foothills of the Olympic Mountains. On the west it is terminated by the ocean. Lithologically these deposits consist of gravels, sands, and clays. The gravels are composed of pebbles, largely of quartzite origin and ranging from one inch to over one foot in diameter. They generally show slight evidences of stratification. The sands, which are very slightly consolidated, are commonly characterized by cross-bedding and often pass into coarse grits. The clays are commonly massive and of a bluish gray color. The sands are nearly always stained a yellowish red. Typical examples of these deposits may be seen in the cliffs along the ocean shore line, as well as in the banks along the river channels which empty into the ocean. This uplifted plain at one time extended much farther out to sea than at present and is rapidly being cut into by the ocean waves. The gravel deposits sometimes constitute the ocean bluffs down to and below the level of the beach. In other places the basal contact gradually rises above sea level, as the older bedrock formations come into view. The probabilities are that if all of these deposits should be removed

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from this particular region under consideration the pre-Pleistocene surface would exist largely below sea level, leaving numerous rock islands off a shore approximately twenty miles east of the present shore line.

Nearly all of the area involved in the Quenaiult Indian Reservation and that part of Grays Harbor County west of Humptulips River south of Grays Harbor is composed of these materials. Their base is almost entirely below sea level. These same deposits extend easterly from Grays Harbor and veneer over much of the area in the valleys of Wishkah and Wynoochee rivers. In eastern Grays Harbor and Mason counties they are replaced by gravels and sands of direct glacial origin.

Along the shores of Willapa and Shoalwater bays there are cliffs ranging from 50 to 300 feet in elevation above sea level, composed of soft incoherent yellowish brown sands, gravels, and clays. They are especially prominent in the vicinity of Bay Center, Nemah River and Long Island. Similar deposits veneer over a large part of the wooded country in the low areas of Pacific County. On the north bank of Columbia River at the town of Ilwaco, horizontal beds of these deposits may be seen resting unconformably upon the upturned strata of the lower Miocene. Deposits of the same nature rest upon the Eocene lavas and sandstones in the vicinity of Grays Bay and eastward into Wahkiakum County.

In the Cowlitz Basin, these deposits occur as terraces along the streams entering Cowlitz River. They generally assume a horizontal position. Excellent exposures may be seen immediately south of Castle Rock and along the river and railway cuts northward from that point towards Olequa. Wherever the pre-Pleistocene topography was composed largely of basaltic rocks, angular fragments of such material enter into the composition of the Pleistocene deposits. In the railroad cuts between Castle Rock and Little Falls, numerous instances of this kind occur. These have been described as Pleistocene lava flows.* Upon examination, however, this lava is found to occur in irregular shaped blocks mixed with sands and river

* Proceedings American Philosophical Society, Volume LII, No. 212, 1913.

gravels, showing conclusively that they have been derived from old rock masses of Eocene age which have been rapidly torn down by weathering and incorporated within the Pleistocene detrital material.

On the slopes of the higher ridges south of Chehalis River, thin layers of yellowish brown sandy clays are found spread over the surface. These are in part of the same origin as the deposits previously mentioned and in part due to extensive long continued rock decay. In these instances the products of rock decay do not appear to have been transported any considerable distance from their original place of formation.

In those areas where basaltic lavas constitute the larger part of the bedrock formations this type of weathering is especially prevalent and attains a thickness of over 50 feet. Wherever suitable exposures have been made, it is found to grade downwards into partially decayed basalt and ultimately into the fresh material. These Pleistocene fluvial deposits which have been uplifted above sea level assume a thickness of at least 400 feet and grade from that downwards to a thin veneer.

MARINE PLEISTOCENE DEPOSITS.

Around the shores of Puget Sound there are numerous raised beaches elevated from fifteen to eighteen feet above sea level. Scattered over the surface of these beaches and embedded in the sands and gravels composing them are the fossil remains of marine molluscs consisting of species very similar to those now living. The Pleistocene marine gravels and sands rest unconformably upon the upturned edges of the older pre-Pleistocene bedrock formations. In places they also lie upon the glacial deposits formed during the last glacial retreat.

Excellent examples of these deposits may be seen around the shores of Restoration Point and on the south side of the entrance to the Bremerton Navy Yard. Similar occurrences exist at Alki Point in Seattle and in places as far north as the San Juan Islands. Deposits which are probably to be correlated with these occur on Vancouver Island. Those on the Saanich Peninsula north of Victoria have been described as the Saanich formation.

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RECENT ALLUVIAL DEPOSITS

In the river valleys unconformably overlying all of the older pre-glacial as well as glacial formations there are deposits of alluvial material which are being deposited at the present time by streams during stages of high water. These materials consist of silts, sands and gravels sometimes intricately mixed but more often somewhat stratified. Examples of these may be seen in the Snoqualmie, Duwamish, Chehalis and Cowlitz valleys. Similar deposits on a smaller scale are forming along the courses of practically all the streams within the state. These deposits vary in thickness and attain a depth of over 100 feet within the larger valleys. In some places bedrock islands project upwards through the floor of the valley alluvium. Examples of this may be seen in Duwamish Valley in the vicinity of South Park and also at Duwamish Station. Other examples which might be cited are the rock islands projecting upward through the Skagit flats.

TIDAL FLAT DEPOSITS.

Near the mouths of the larger rivers there are broad tidal flats which during high tides are covered with water but during periods of low tide appear as extensive mud flats. Winding sloughs cross these. The deposits are generally composed of a massive bluish gray clay. The best examples of this type are to be found at the south end of Shoalwater Bay, Willapa Harbor, Grays Harbor, the mouth of Columbia River and in many of the small embayments in Puget Sound.

SAND DUNES.

Sand dunes are confined chiefly to the Pacific coast of Washington and Puget Sound. They occur on the long sand spit extending northward from the mouth of the Columbia River to the entrance to Willapa Harbor. Another prominent sand spit extends from the north side of the entrance to Willapa Harbor northward to Grays Harbor. These spits average three miles in width and range up to 25 feet above sea level. They are composed chiefly of wind blown sand which in many places support considerable vegetation.

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CHAPTER VII.

GEOLOGIC STRUCTURE AND HISTORY.

GEOLOGIC STRUCTURE.

GENERAL STATEMENT.

Investigations carried on by Russell, Smith and Willis in the central portion of the Cascade Mountains of Washington show that the formations of that area have been warped into a series of folds whose axes trend from southeast to northwest. One of these extends from Columbia River along the axis of the Wenatchee Mountains. A second trends along the Entiat Mountains to the summit of the Cascades. A third lies south of Yakima River. All three are approximately parallel.

A glance at the structure map of western Washington accompanying this report will show three prominent structural features which are designated as differential elongated upwarps. (Plate XXX.) These appear to rank in value with those described by Willis and Smith on the eastern side of the Cascades. There is a prominent downfold extending in a north and south direction the length of the state, nearly at right angles to the upwarps. This downfold is known as the Puget Sound-Cowlitz Valley depression which is a part of a well defined downfold extending from the great valley of California to Queen Charlotte Sound. It is possible, however, that in Washington this downfold may have been formed in part by north-south faulting.

THE SKAGIT-SAN JUAN-VANCOUVER ISLAND UPWARP.

This prominent topographical and structural feature extends from the south side of Skagit Valley and passes out to the Puget Sound depression near the mouth of Skagit River. It extends through the San Juan Islands and thence northwesterly into the heart of Vancouver Island. This apparently is the northwesterly extension of the Entiat warp on the eastern flank of the Cascades. The formations involved along this upwarp are of approximately the same geologic age, viz., Carboniferous and early Mesozoic. They consist of quartzites, slates,

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schists, crystalline limestones and a complex series of Mesozoic intrusives. A pronounced sag has been developed nearly at right angles to the axis of this upwarp in the region of the San Juan Islands. This sag is a part of the Puget Sound-Cowlitz basin depression. On both the north and south flanks of this upwarp are parallel axial downfolds, one trending along the Strait of Georgia towards Frazier River and the other along the Strait of Juan de Fuca and across Puget Sound towards the lower valley of Snoqualmie River.

NEWCASTLE-OLYMPIC UPWARP.

The position of this axial upwarp extends from the summit of the Cascades in the vicinity of Mt. Stuart northwesterly through King County and on through the Newcastle Hills and Seattle into Kitsap County. In Kitsap County it involves the Bald Hills and from there extends northwesterly through the main axis of the Olympic Mountains, and possibly out to Cape Flattery. Mt. Olympus lies along this axis. In the Newcastle Hills the older Eocene rocks are brought to the surface and above it so as to form a prominent topographic feature. The later Miocene rocks which overlie the Eocene are absent along the crest of the upwarp but are well developed to the north in the downwarp. In the region where the transverse Puget Sound depression crosses this upwarp, a sag has been developed and only remnants of the bedrock formation project above sea level. They are represented by the Eocene deposits about Duwamish Station, the basaltic masses in the Bald Hills of Kitsap County and the upturned Oligocene formations which flank its north border at Bremerton Inlet. The semi-metamorphosed sediments of the Olympic Mountains have been highly tilted and the strike is approximately parallel to the trend of the axis of the upwarp. A pronounced downwarp lies to the north and parallel to the axis just described. It has been filled with Miocene sediments which in turn have been subjected to extreme folding.

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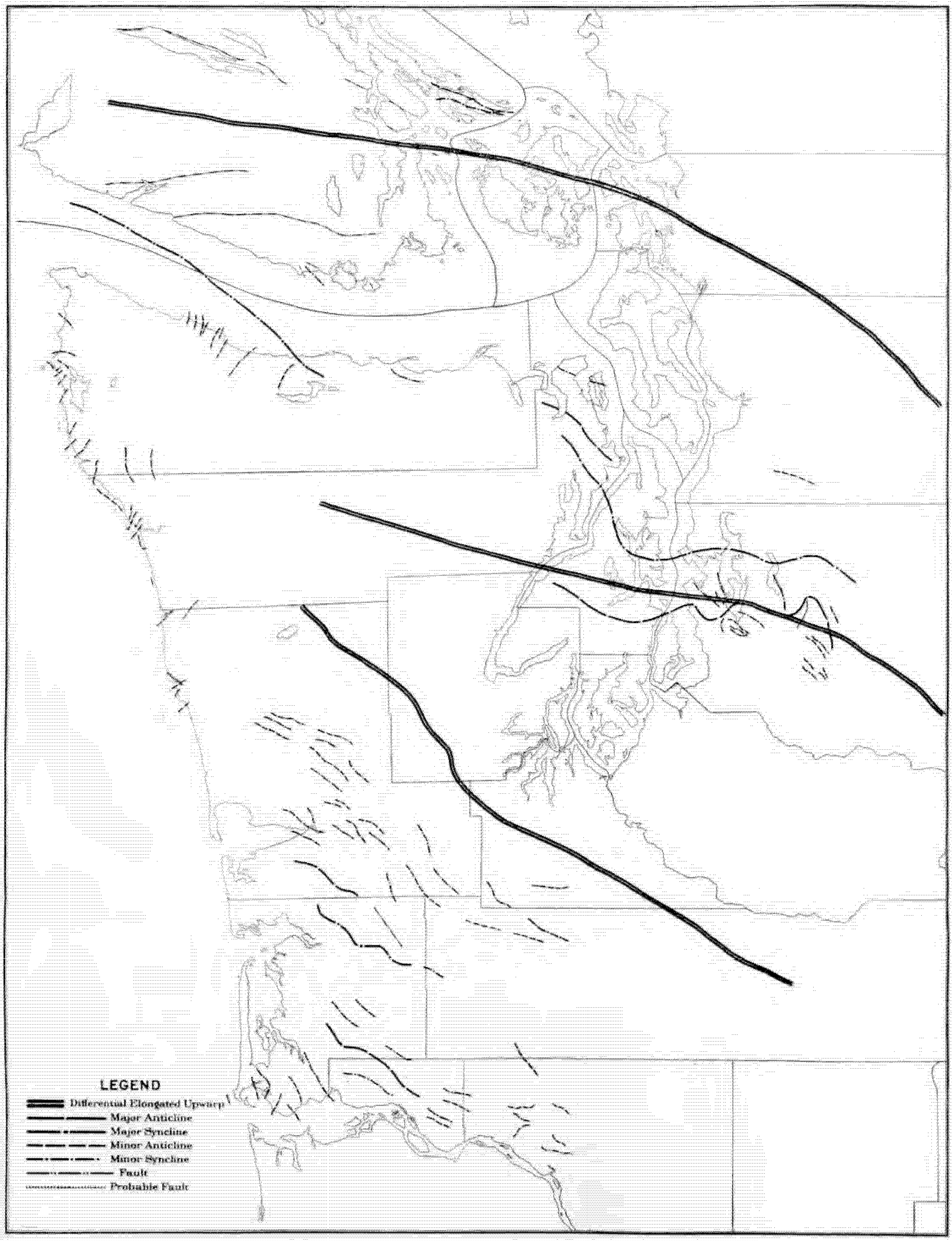

Structural Geologic Map of Western Washington.

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BLACK HILLS UPWARP.

The third upwarp in the western part of the state extends from the Cascades in Lewis County northwesterly through Thurston into Mason and northeastern Garys Harbor County. In this upwarp are involved the high mountain ridges forming the divide between the Cowlitz and Nisqually rivers. In Thurston County it constitutes the low divide between Puget Sound and Grays Harbor. In this region it is crossed by the north-south Puget Sound-Cowlitz Valley depression. To the northwest in the Black Hills the elevations increase to over fifteen hundred feet. The Black Hills are composed of extensive areas of basalt of Eocene age. From this point the upwarp passes into the southern portion of the Olympic Mountains. Its relation in the vicinity of Queniult Lake to the main Olympic axis has not been definitely determined.

On the southwestern side of this upwarp in southwestern Washington the Eocene formations pass below sea level and are covered with extensive deposits of Oligocene and Miocene age. These have also been folded into minor anticlines and synclines which may be seen on the structural map.

Two well-defined anticlinal axes trend in a northwesterly-southeasterly direction through Pacific County but are not to be regarded as of the same importance as the three just described.

Downwarps have already been referred to in the discussion of the upwarps. There are four of these in western Washington. The most northerly lies along the north side of Vancouver Island and extends into Whatcom County. Between the Skagit-Vancouver and the Newcastle-Olympic upwarps, there is a pronounced downfold trending parallel to the Strait of Juan de Fuca southeasterly into Snohomish County. Between the Newcastle-Olympic and Black Hills upwarps there is a downfold whose extent has not been definitely determined. In the Puget Sound Basin area it is deeply filled with glacial drift deposits. A fourth axial downfold trends from Grays Harbor southeasterly to the Cowlitz Basin.

ANTICLINES AND SYNCLINES.

Upon the structural map accompanying this report have been platted all the important anticlinal and synclinal folds which could be definitely determined. These have been grouped into two broad divisions, viz., major and minor anticlines and synclines. The former includes those folds which constitute an important structural unit over a considerable geographical area. The latter are those which have been developed as minor folds on the flanks of or subsidiary to the major folds. One major anticline designated upon the map as the Newcastle anticline passes nearly east and west through central King County. Its actual position as nearly as can be determined is shown on Map B, Plate IV. Its axis swings in a sinuous fashion but still maintains its nearly east to west direction. To the north there is a broad synclinal basin. In the eastern portion of Puget Sound Basin its exact position cannot be absolutely determined. Its northwestern extension, however, can be traced into Jefferson County as has been indicated upon Map C, Plate IV. A second major anticline trends across the Quimper Peninsula from Hood Head to Port Discovery Bay. From Lake Crescent in Clallam County a well-defined synclinal trough extends northwesterly and enters the Strait of Juan de Fuca. Its exact position in the Strait, of course, cannot be determined. The Vancouver Island shore is skirted with lower Miocene strata, dipping at low angles to the southwest, although they are in places involved in minor axial folds transverse to the main synclinal trough. Along the south side of the Strait, minor anticlinal and synclinal folds are well developed from Gettysburg to Cape Flattery. They represent minor wrinkles on the southwest limb of the synclinal trough. The Cape Flattery monocline apparently represents the true southwest limb.

On Vancouver Island between Sooke Bay and Sherringham Point a shallow synclinal trough exists but it is apparently subsidiary to the main synclinal trough of the Strait. All of the above mentioned minor folds are involved in the downfold between the Skagit-Vancouver and Newcastle-Olympic upwarps.

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In the vicinity of Seattle and eastward numerous transverse folds have been developed on the flanks of the Newcastle anticline. In the Pierce County coal fields the anticlinal and synclinal folds are pitching to the north. In the Green River area in King County similar folds are pitching southward. Apparently a northwest-southeast downfold intersects them and trends approximately along the boundary line between King and Pierce counties.

In southwestern Washington, Eocene and Miocene deposits have been folded into numerous parallel anticlines and synclines trending North 65° West. One major anticlinal axis trends from the south side of Grays Harbor to the northeastern corner of Pacific County and along it the older Eocene basalts come to the surface. On the northeastern side of this fold the Miocene strata form the surface outcrops and have been folded into a series of parallel minor anticlines and synclines pitching northwesterly towards the ocean.

Farther to the southwest a parallel major anticline trends from Shoalwater Bay southeasterly into Wahkiakum County. The core as exposed at the surface is also composed of Eocene basalts. Between the two major anticlines just described a shallow synclinal trough exists. In it only the very basal portion of the Miocene sediments are involved. To the southwest toward Ilwaco several smaller folds occur. The strata involved in them are Oligocene and they occupy a downfold. The Eocene basalts are again brought to the surface at Ilwaco Point. In the vicinity of Fort Columbia on Columbia River, basalt flows occur, interbedded with the lower portion of the Oligocene strata. These minor folds extend across Columbia River and may be seen as shallow folds within the town of Astoria in Oregon.

On the Pacific Coast from Grays Harbor northward to Cape Flattery a large number of folds have been formed in the Hoh formation. A broad anticlinal fold extends from Forks postoffice on the Bogachiel River southward into Jefferson County. Its southward extension has not been definitely determined. To the west of this anticlinal fold a synclinal fold has been developed approximately parallel to the coast line. The western limb of this syncline has been developed into a series of transverse folds, having an average trend of North 30° East. Nearly all of these are intersected by the coast line and their position has been definitely determined. Their true position may be seen by referring to Map A, Plate IV, as well as on the structural map, Plate XI. The above described structure is terminated by the long axis extending out towards Cape Flattery and perhaps by an extensive fault extending from Point of the Arches southeasterly up Soleduck River.

TIME OF FOLDING.

The three main structural upwarps may have been initiated at the close of the Jurassic. No definitely known Cretaceous rocks are known in the Olympic Mountains. They do, however, skirt the north shore of Vancouver Island and extend into northern Whatcom County. Apparently Vancouver Island, the Olympic Mountains and the northern Cascades south of the Skagit River were land areas during the Cretaceous. The Eocene, Miocene and Pliocene formations are absent from the central portion of the Olympics and Vancouver Island. It would appear that deformational movements produced uplifts along these upwarps so as to bring a part of the sea floor above sea level. A transverse downfold along the Puget Sound-Cowlitz Valley depression perhaps was also initiated at this time. As a result of these earth making movements, it is probable that the embayments in which Eocene sediments accumulated, were formed. At least these movements must have helped to influence their distribution. Near the beginning of the Oligocene epoch movements of the crust in this part of the state seem to again have produced downfolding and upfolding along these same lines of folding. New basins of deposition were developed, chiefly in the synclinal trough along the Strait of Juan de Fuca to King County and from Grays Harbor south to the Columbia River.

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At the close of the Oligocene epoch the marine strata which had been deposited during that time were folded and uplifted and apparently raised high above sea level. The localities of greatest uplift appear to have been along the areas of the three upwarps as shown upon the structural map.

Near the close of the Pliocene the Cascade Mountains were brought into their present position. During the elevation of this peneplained surface the formations were being developed into shallow elongated folds as indicated upon the structural map of western Washington. The Pliocene uplift is believed by the writer to have been an intensified upward movement along the axes of the same upwarps which had their beginning possibly at the close of the Jurassic. As a result of studies in the western part of the state it seems probable that differential diastrophic movements were taking place with varying intensity from the Cretaceous to the Pleistocene and along the same major lines of folding or upwarp. The times of most intense movement were at the close of the Jurassic, the Oligocene, the lower Miocene and near the close of the Pliocene. The present topography and structure probably in part owes its origin to diastrophic movements initiated at or near the close of the Jurassic and to a continuation of those movements during the Tertiary in a more or less intensified form. At the close of the Pliocene the most important folding occurred.

FAULTS.

Because of the dense covering of vegetation and of Pleistocene deposits it has been impossible to determine many faults which undoubtedly exist. Detailed studies have been made in the King and Pierce county coal fields and numerous faults were encountered. Many of these show a displacement of only a few feet, while others are displaced more than 1500 feet. The prevailing directions are northwest and southeast. In southwestern Washington many faults of small extent occur but are not of sufficient importance to be represented upon the map of a scale used in this report. North of Cape Elizabeth along the shore a fault occurs which extends southeasterly and intersects

Queniult River about four miles from its mouth. The upper Miocene strata rest against those of the older Hoh formation along the fault plane.

Farther north on the coast a possible fault extends from the north side of Portage Head southeasterly and crosses Hoko River in Section 24, Township 31 North, Range 14 West. From that point it passes into the Olympic Mountains and has not been examined. A similar fault may exist on the south side of Point of Arches and trends parallel to the one just mentioned, but the evidence is not conclusive.

On Vancouver Island two faults occur extending nearly east and west. The south fault extends from Sombrio Point towards Victoria and separates the Eocene basalts on the south from the older Mesozoic metamorphics on the north. The data concerning faulting on Vancouver Island have been determined by Charles H. Clapp of the Canadian Geological Survey* and to him should be given full credit for this information. The basalts which were mapped by him as the Metchosin formation were considered to be of early Mesozoic age but Tejon fossils have been found in the tuff phase at Albert Head, proving it to be of Eocene age. It seems best to incorporate this data as it has a direct bearing on the structure in Washington.

GEOLOGIC HISTORY.

Very little data is at hand concerning the geological history of western Washington during the Paleozoic, especially the earlier half. In the northern Cascade Mountains, in the San Juan Islands and on Vancouver Island, an extensive series of metamorphic rocks are found which in places contain Crinoid remains. The species cannot be exactly determined but they strongly suggest a Carboniferous age. From the lithologic character of the materials occurring within these presumable Carboniferous strata, it is possible to imagine the probable geologic conditions which then existed.

The larger portion of western Washington appears to have been part of an extensive marine area which was probably con-

* Memoir Number 13—Geological Survey of Canada, 1912.

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nected with embayments which were definitely known to exist in Idaho, Oregon, Nevada and California. The indications on Vancouver Island and in the northern Cascades point to the occurrence of numerous islands, some of which may have been in the nature of volcanic cones. Volcanic activity appears to have taken place in this region during the Carboniferous. Deposits of volcanic ash as well as lavas are found interbedded with the Carboniferous sedimentaries.

At present there seems to be no way of distinguishing between the Carboniferous and Triassic formations in the western part of the state. Detailed studies in the future may permit such distinctions to be made. As far as we are able to judge at present the geographical and climatic conditions during the Triassic were very similar to those during the Carboniferous. Tropical conditions prevailed during both periods.

The Cascades at this time did not exist in their present condition. The Peshastin formation in eastern Washington, the Gunn Peak formation in the Skykomish valley and the old metamorphic rocks of the Skagit valley are presumably of the same age and were deposited during the Carboniferous and Triassic. If this assumption be correct, the open seas occupied all of northwestern Washington, including the present site of the Cascades. In southwestern Washington and northwestern Oregon the upper surface of the Triassic and Carboniferous rocks is far below sea-level and is covered with an enormous thickness of later Tertiary formations. Nothing is known concerning the character of the Carboniferous and Triassic seas in that region.

Very little is known concerning the Jurassic in western Washington. On the western slope of the Olympic mountains a thick series of semi-metamorphosed strata which have been designated as the Hoh formation are provisionally assigned to the Jurassic. If this assumption be correct, we may consider the present site of the Olympic Mountains as having been under water during Jurassic time.

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Towards the close of the Jurassic, volcanic activity began on an extensive scale. Great masses of igneous materials were injected into the earth's crust in the form of batholiths. These were first of basic or ultra basic composition. Following this came intrusions of granodiorite. This igneous activity in Washington was a phase of similar invasions which were common to the entire Pacific Coast from Mexico to Alaska. In the Cascades these intrusives are represented by the great masses of peridotite and Mt. Stuart granodiorite, as well as the Index granodiorite. Accompanying this igneous activity or just following it, important deformational movements began.

No deposits of lower Cretaceous or Knoxville age are known within the state of Washington. The larger part of the state is covered with formations of a later period and it is possible that the lower Cretaceous may be buried beneath. In the northern part of the state the upper Cretaceous or Chico strata are present and represent an embayment which was developed in British Columbia, and extended southward into San Juan and Whatcom counties. This sea extended over the northeastern part of Vancouver Island. Submergence appears to have been rapid during the early part of the Chico epoch but toward the close the seas became shallower as attested to by the massive sandstones and conglomerates which constitute the upper part of the Chico as exposed upon Vancouver Island.

There is no definite evidence concerning the geologic and geographic conditions in western Washington during the early part of the Eocene epoch. Presumably the entire area was slightly elevated above sea level. In southwestern Washington and in the Puget Sound Basin formations of upper Eocene age occur which can be correlated with the Tejon formation of California.

During the upper Eocene the Cascade Mountains were not in existence. The Olympic Mountains were presumably a land area of considerable elevation and were separated from the mountains of Vancouver Island by a downfold which at times was partly submerged. Early during the Tejon epoch south-

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western Washington was invaded by an embayment from the ocean. The shore line ultimately reached the present site of the foothills of the Cascades but did not connect with the fresh water lakes on the eastern side. An arm of this embayment extended into the Puget Sound Basin and even for some distance into the Strait of Juan de Fuca. Large estuaries existed to the east of the marine embayments and emptied into them. To the east in the central portion of the present site of the Cascade Mountains there were lakes whose shore lines were probably not far above sea level.

During the progress of the Tejon epoch the surface of the land areas as well as the floor of the embayments were undergoing differential upward and downward movements. The shore lines were advancing and retreating. Estuarine conditions were becoming marine for a time and then reverting back to estuarine. Tropical climates prevailed allowing the development of a rich invertebrate marine fauna as well as a tropical flora. Palms and giant ferns were growing on the low swampy lands bordering the estuaries and lakes. The alternate elevations and depressions of the land caused the growth and burial of tropical forests which are preserved in the form of carbonaceous shales and coal seams. Occasionally basic lavas were being erupted presumably in part through fissures and possibly in part through small volcanic cones. Deposits of ash and flows of lava were formed both on the land and upon the floors of the embayments. In the Cascade Mountains two large lakes were developed. The earlier lake basin allowed the accumulation of the sandstones and shales which have been described as the Swauk formation. This lake was finally drained presumably through one of the estuaries in King and Pierce counties to the marine embayments. The deposits which had formed within it were slightly folded and then invaded by basaltic magmas which arose through numerous parallel fissures and accumulated upon the surface as the Teanaway basalt. Later diastrophic movements developed another drainage basin in which the sediments of the Roslyn formation were laid down. Later this lake was

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also drained and the waters presumably found their way to the west into the ocean. Probably the same movements which were disturbing the land areas on the present site of the Cascades were effecting the embayments to the west. It is possible that the great lithologic variations in the character of the estuarine sediments of King and Pierce counties may have had some connection with the draining of Swauk and Roslyn lakes of the central Cascades. In eastern Washington volcanic activity was more or less prevalent during the entire Tertiary period. In western Washington it was almost entirely confined to the Eocene epoch and to the Quaternary. This statement does not apply to the western foothills of the Cascade Mountains.

Early in the Oligocene epoch there was a more general subsidence in the western part of the state. Marine embayments extended slightly farther east than during the Eocene epoch. The extensive estuaries which were in existence during the Eocene disappeared. The marine faunas underwent evolutionary changes and many species characteristic of late Tertiary and recent time made their first appearance. During the progress of Oligocene time the faunas were undergoing changes but even at the close of the epoch the most important genera showed tropical characteristics. During the later portion of the Oligocene epoch the marine embayments became most widely spread. The larger portion of the Puget Sound Basin became an embayment and it is possible that the waters of the ocean gained access through the Strait of Juan de Fuca rather than through southwestern Washington. There may have been a land connection between the Olympic Mountains and the present site of the Cascades.

During both the Eocene and Oligocene and probably the Cretaceous the Olympic Mountains were presumably undergoing vigorous erosion and possibly had reached a condition of peneplanation by the middle of the Oligocene epoch. Many of the higher peaks of the Olympic Range are monadnocks upon the surface of the peneplain.

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At the close of the Oligocene there was a slight elevation of the western portion of the state which resulted in the withdrawal of the marine embayments over considerable areas. The Puget Sound Basin appears to have been entirely drained as well as a large portion of the eastern Juan de Fuca downfold. Smaller embayments still existed to the north of Columbia River in Pacific and Wahkiakum counties as well as in the Grays Harbor region. On the whole shallow water seas prevailed and in these a marine fauna lived representative of a colder climate than during the Oligocene. At the close of the lower Miocene the entire Pacific Coast was effected by marked diastrophic movements which brought the entire western portion of Washington above sea level. During the Oligocene and lower Miocene epochs a maximum of 18,000 feet of sediments were deposited in marine embayments. At the close of the lower Miocene these deposits were folded and uplifted.

At the opening of the upper Miocene epoch two local embayments were developed. One of these existed in southwestern Clallam County near the junction of the Soldue and Bogachiel rivers and the other was to the east and north of Grays Harbor. During most of the epoch the waters in these embayments were shallow and contained a marine invertebrate fauna strikingly different from the Oligocene and lower Miocene faunas. The coarse grained and cross bedded character of the sediments indicate the existence of sand bars or spits somewhat similar to those protecting Shoalwater Bay and Grays Harbor to-day. By the close of the Miocene or at least early in the Pliocene these two areas were elevated above sea level. Apparently the land area of the state extended much farther seaward than at the present time.

During the Pliocene epoch all of western as well as eastern Washington was a land area. No marine deposits are known to occur within the state. The present site of the Cascade Mountains was undergoing vigorous erosion and being reduced to a peneplain. The Olympic Mountains were presumably more highly elevated than the Cascades but were still in a peneplain condition. The pre-Pleistocene topography of the Puget Sound Basin was being developed during this epoch. The history of the Pliocene in Washington is a record of diastrophism and erosion which at the present time is not very well known.

At the close of the Pliocene or early in the Quaternary, mountain making movements were taking place throughout the entire Pacific Coast. The present Cascade Range of Washington and Oregon as well as the Sierra Nevadas of California were uplifted. The Olympic Mountains and the major portion of Vancouver Island were also elevated to an elevation of at least 5,000 feet. During the process of uplift the peneplain surface of the Cascades was slightly warped into a series of northwest and southeast shallow folds. The more important drainage features of the range were partly dependent upon the positions of these folds. In both the Cascades and Olympics the peneplain surfaces were immediately attacked by erosional agencies and the dissection of the uplifted masses begun. In the Olympic Mountains such peaks as Mt. Constance, Angeles, Eleanor, the Brothers and Olympus are residual monadnocks upon the surface of the original peneplain. The principal river valleys of the range have been carved down into the uplifted peneplain surface of the mountains. Upon the uplifted peneplain surface of the Cascade Mountains volcanic cones were built up, such as Mts. Rainier, Baker, Adams, St. Helens and Glacier Peak. Volcanic peaks are entirely absent from the Olympic Mountains. The peaks in that range are composed of metamorphic rock which because of their resistance to erosion have been left as monadnocks.

After the volcanic cones of the Cascades had been formed and the range had undergone vigorous erosion the greater portion of western Washington was subjected to glaciation. The two main advances of the ice, with the record of an interglacial epoch, were described in a previous chapter.

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CHAPTER VIII.

PETROLEUM DEPOSITS.

GENERAL STATEMENT.

Petroleum is essentially a mixture of several organic compounds composed for the most part of hydrogen and carbon united in the form of hydrocarbons of variable composition. In association with these there are usually small amounts of oxygen, sulphur and nitrogen. There are various kinds of petroleum but they are usually grouped into three classes—the paraffin type, the asphaltic type and the olefine type. The paraffin types are the source of most of the refined petroleum. The asphaltic types constitute a source for fuel oil and oil asphalt. The olefine type is a source for both fuel and refining purposes. Asphaltic oils when slowly distilled yield a dark residue of asphaltic material which is easily soluble in acids. Paraffin oils when slowly heated yield on reduction a considerable amount of light colored solid hydrocarbons which belong mostly to the paraffin series, and are not easily attacked by acids.

Nearly all asphaltic oils as a rule contain traces of solid paraffin and the majority of paraffin oils contain asphaltic products. As a rule crude petroleums of one type do not contain undue proportions of another type. All crude petroleums possessing either an asphaltic or paraffin character are composed of a mixture of hydrocarbons of different boiling points and densities. The various hydrocarbons constituting such petroleums when subjected to heat are evolved whenever the temperature of their boiling points is reached.

In most oil bearing districts in different parts of the world, the members of the paraffin series of hydrocarbons form one of the chief constituents of petroleum. The higher members of this series which are usually solid are comparatively rare. Methane, CH_4, is the lowest member of this series and occurs as a gas. It is present in solution in large quantities in most oils and also occurs as one of the chief constituents of natural gas.

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It is a saturated hydrocarbon and upon analysis normally is found to contain 75 per cent. of hydrogen and 25 per cent. of carbon. In addition to oxygen and nitrogen, other organic constituents which may be present in the form of ash, are calcium, iron, aluminum, copper oxide, silver, arsenic and phosphorous, all of which occur only in exceedingly small amounts.

Petroleum ranges in color from a brownish black to reddish green and yellow and in specific gravity from .780 to 1.0. In a crude state it is a viscous liquid.

SOURCE OF PETROLEUM DEPOSITS.

Geologists are almost unanimously of the opinion that nearly all petroleum deposits are derived from organic sources and not from inorganic. Those who have advanced the inorganic theory of origin are largely chemists. Their ideas have been deduced from experimental data in the laboratory and not as a rule from the geological occurrences of such deposits in the field.

It is believed that in most cases petroleum has arisen from the remains of animal life which formerly was in existence during past geological periods. In some cases plant life has acted as a source. Chemical examinations of living animal organisms show that they are composed largely of fatty materials, while plants are for the most part composed of cellulose. Certain plants of low development in the biologic scale such as diatoms have fats as their chief constituent. Analyses of petroleum compounds show that the chemical substances entering into them are more closely related to fats than to cellulose.

At various times experiments have been performed in the laboratory to bring out certain relationships between the chemical composition of petroleum as compared with that of animal life. In 1888, Engler distilled 490 kilograms of fish oil and obtained a distillate similar to petroleum. Distillation was commenced at a temperature of 320° C, under a pressure of 4 atmospheres. He obtained 60% of distillate which had a specific gravity of 0.8105. From the distillate a light oil indistinguishable from commercial kerosene was obtained.

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In most oil bearing districts there appears to be a more or less definite relationship between the presence of fossil animal remains and the strata containing the petroleum deposits. On the island of Trinidad there are extensive asphalt deposits which occur in asphalt lakes. The strata associated with these asphalts contain vast numbers of microscopic marine organisms known as Foraminifera. It is possible that the soft organic tissues of these organisms after having undergone chemical changes may have been the source of the petroleum.

In Scotland there are shales heavily charged with petroleum which are known as oil shales. Upon distillation they yield considerable amounts of liquid petroleum. Associated with these shales are large quantities of fossil fish remains. There may have been a genetic relationship between the petroleum and the original soft organic fats of the fish.

In the Mississippi Basin and in the Appalachian states there are extensive belts of limestone of Palaeozoic age which were in part formed from the hard calcareous remains of marine animal life. These organisms originally contained soft organic tissues. The oil and gas deposits of these areas are associated with the limestones or the overlying or underlying sandstones or shales. There may be a relationship between the petroleum and the original organic life of those regions. In Mexico similar relations exist between the Cretaceous limestones and the deposits of oil.

The soft organic fats from fossil microscopic marine diatoms may have been the source of the petroleum in the oil fields of southern California. During the lower Miocene a portion of the Coast Ranges of California was an arm or embayment of the ocean. Within this embayment there swarmed uncountable numbers of diatoms. During the existence of this sea environmental conditions appear to have been favorable for the continuous development of these forms of life. As a result a formation was built up consisting in part of deposits largely composed of the siliceous remains of diatoms. These siliceous shales are known as diatomaceous shales. They have a direct relationship to the occurrence of petroleum deposits in the California field. Sandstones occur below, above and interbedded with these shales, and wherever they come in contact with the diatomaceous shales or cherts, they usually contain petroleum. Wherever the sandstones are present and the diatomaceous shales are absent the former are usually barren of petroleum. In other words the sandstones act as a retainer for the oil and gas and the diatomaceous shales have been the source of supply.

To many people there is a general impression that there exists a definite relationship between the occurrences of coal and oil. From a genetic standpoint they are unrelated. Distillations of coal do not give rise to chemical compounds of a character similar to petroleum. Oil may occur in strata of the same geological age as coal deposits. It may even occur with coal but when such a condition obtains, each usually has been derived from a different source.

GEOLOGIC DISTRIBUTION OF PETROLEUM DEPOSITS.

Deposits of petroleum and gas in varying amounts have been found in the strata of all periods from the Cambrian to the Pliocene. As a rule in any one locality petroleum is usually confined to the strata of one or two periods. In the Appalachian and Mississippi Basin regions petroleum and natural gas are found in the Palaeozoic strata. During the Mesozoic and Tertiary these regions were largely land areas and conditions suitable for the development of petroleum did not exist. .n Louisiana and southern Texas petroleum and gas are found in the Cretaceous, Eocene and Miocene strata. On the Pacific coast of California there exist strata of Palaeozoic, Mesozoic and Tertiary age. The Palaeozoic formations occur only in scattered areas and are almost barren of petroleum and gas. There are enormous thicknesses of Cretaceous and Tertiary rock in the Coast Ranges. Nearly all the petroleum deposits occur within the Tertiary formations.

Examinations which have been made of oil bearing districts in different parts of the world indicate definitely that petroleum

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may occur in strata of any geologic period. During any one period, geologic conditions in one locality may have been favorable for the formation and accumulation of oil and gas and in some other locality perhaps not far away those conditions did not exist. The result is that the rocks formed at the same time in one locality may be entirely barren and in another contain rich deposits of oil.

RELATION OF GEOLOGIC STRUCTURE TO THE OCCURRENCE OF PETROLEUM.

Geologic structure has a very important bearing upon the occurrence of oil and gas. When present in any region they are usually associated with sedimentary rocks. They are very generally absent from igneous or metamorphic rocks. Sedimentary strata are usually composed of alternating layers of sandstone, conglomerate, shale and sometimes limestone. Very often these grade into one another. In most regions oil bearing or other strata are sometimes thoroughly permeated with water which tends to flow as an underground current. In many cases, especially in oil producing districts, this water is heavily charged with chlorides. Sandstone is a much more porous rock than shale and if oil or water, or both, are present they accumulate in it to a greater extent than in the shale, which acts as an impervious layer. As the water and oil circulate through the sandstone zones they tend to partially separate according to the laws of gravity.

As a result of investigations which have been carried on in many parts of the world it has been demonstrated that there are very few instances where sedimentary rocks lie absolutely horizontal. At the present time almost no part of the earth's crust is remaining entirely stationary. Differential movements are taking place resulting in depression in some localities and elevation in others. Sometimes these movements are extremely slow and at other times they take place with considerable rapidity. The combined result of such disturbances is to throw originally horizontal strata into wavelike undulations. These are generally referred to as folds and the upward portion of them

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as anticlines. The lower or downfolded portions are spoken of as synclines. The line on the surface following the highest points of an anticlinal fold is known as an anticlinal axis. The angle of slope of the strata on the flanks of an anticline may range from less than one degree to ninety degrees. Sometimes originally horizontal strata may be slightly bulged upward toward a point on the surface. The structure of such a mass would appear similar to a very much flattened cone and the angle of slope of the surface of the cone might vary slightly from place to place. Such structures occurring in nature are known as domes.

When a series of horizontal strata such as have already been described contain water or oil or both, are capped over with impervious shale layers and are then folded into domes or anticlines, the water and oil will tend to circulate along the undulations of the strata. They also tend to maintain the same gravity relations as they formerly did when the strata were horizontal. To a certain extent the water circulates below and the oil above. After the strata have been folded the oil will tend to rise to the highest points possible in the undulating layers of sandstone, and that will be beneath the axes of the anticlines or the apices of the domes. The result is that as the oil and water circulate in the undulating stratum of sandstone a large portion of the petroleum will accumulate toward the axis of the upfold leaving less and less in the downfold or syncline. As a result whenever a well is bored at some point along the axis of an anticline or on the upper portion of a dome and an oil bearing sandstone is tapped, petroleum and gas may rush to the surface in the form of a gusher or it may be necessary to extract it by pumping. If a well be bored along the axis of a syncline and the oil bearing sandstone zone be reached salt water instead of oil may be obtained. These facts have been recognized in practically all the oil producing fields of the world. Such field data as will record the position of anticlines and synclines is among the most important which a geologist seeks in making an examination of an oil district.

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In a few instances it happens that there are oil bearing sandstones in which petroleum deposits are present but where water is absent. In such cases, the oil tends to circulate through the sandstone but since no water is present it is not forced to the upper portion of the sandstone zone. It permeates the whole sandstone stratum from top to base or perhaps is present in larger amount near the base. It does not however, as before, tend to accumulate near the axes of anticlines but rather in the synclinal troughs. Such conditions are extremely rare.

It is of very common occurrence in most oil districts that there are several strata of oil bearing sandstone alternating with impervious layers of shale. Each sandstone zone may be considered as an oil reservoir independent of all the other sandstone zones. It would be possible to tap an upper zone and extract all the petroleum within it and not in the least disturb that in the zones beneath. After such a sequence of strata have been formed and folded into anticlines and synclines, they are ordinarily subjected to erosion. Such erosion may be sufficiently vigorous to remove a portion of the overlying shale stratum and allow a small part of the oil bearing sandstone zone to become exposed to the atmosphere. When this occurs the more volatile constituents of the petroleum will tend to evaporate and ultimately leave behind a viscous or solid mass of black asphaltum or light colored paraffin. Such occurrences are to be found on the island of Trinidad in the West Indies and in the Lake Athabaska region of Alberta. It is to be inferred from the occurrence of an asphaltum outcrop upon the surface that at least one oil bearing stratum has by natural processes been destroyed as a petroleum producer, but it does not indicate that there are no more petroleum bearing zones below. In most regions where oil deposits are known to occur and where the associated strata have been folded into anticlines and synclines by minor or major stresses, breaks or cracks have been developed. These are geologically known as faults. They may extend from the surface downward for considerable distances. Occasionally such faults may branch and some of the branches may tap oil

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bearing sandstones. When such a condition occurs the lighter constituents of the petroleum may in small amounts travel along these cracks toward the surface. Seepages of oil may reach the surface immediately above its source, or some distance away. It may reach the surface at the axis of an anticline or somewhere along the axis of a syncline or in between. As a result it is apparent that if an underground accumulation of petroleum be present it is not necessarily directly below or in the near vicinity of a surface seepage.

POSSIBLE OCCURRENCES OF PETROLEUM IN WESTERN WASHINGTON.

There are conditions in certain geologic formations within this state which absolutely prohibit the occurrence of petroleum deposits. In certain other formations petroleum might occur and in still others there is definite proof that it is present, but whether in commercial quantities or not, has not been demonstrated. The conditions which would allow of its occurrence are, first, the presence or former presence of some material from which it could be derived; second, the presence of some sedimentary strata which could act as a retaining reservoir; third, the presence of some impervious capping such as a shale or clay stratum to prevent its escape to the surface; fourth, an arching of the strata either into domes or anticlines to allow of its segregation. The presence of metamorphic rocks or igneous rocks are highly unfavorable to the occurrence of petroleum within them. In formations, however, that have been metamorphosed there might be local areas which have escaped or are only semi-metamorphosed. In such formations, if all other conditions are present, petroleum deposits might occur. In the examination of the geology in any particular district it is necessary to determine in how far the above conditions apply, and upon such a basis to decide whether the possibilities for the occurrence of petroleum deposits are favorable or unfavorable.

It often happens that on the surfaces of ponds or marsh areas an irridescent scum appears which is commonly mistaken

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for an indication of oil. Occasionally marsh gas may also escape from such areas and convince an observer that oil deposits occur below. In regions where iron oxide forms a part of the cementing material of sediments or is a residual from rock decay, it may also collect as a scum around the opening of a spring or on a stagnant pool of water. A chemical examination of such deposits would show that they have no relation to the occurrence of petroleum.

CASCADE MOUNTAINS.

The Cascade Mountains are composed for the larger part of igneous and metamorphic rocks. A few scattered areas of Eocene and Miocene lacustrine sediments occur in several places, but no large quantities of organic animal remains have been found within them which could give rise to petroleum. In the northern Cascades there are extensive areas of granite and other deep seated rocks. In the southern portion of the Cascades the old granite and metamorphic surface passes down to or below sea level and is covered with an extensive series of lavas and tuffs. The Cascade Mountains as a whole may be eliminated as a possible source for petroleum.

PUGET SOUND BASIN.

GLACIAL DEPOSITS.

The larger portion of the Puget Sound Basin exclusive of that occupied with marine waters is more or less heavily veneered with deposits of glacial drift. These vary extensively in composition from place to place. They are composed of stratified and non-stratified gravels, sands and clays which in most cases have been transported for considerable distances by glaciers. During the advance of the ice sheet into the Puget Sound Region extensive scouring and erosion of the pre-glacial rocks was accomplished. During the retreat of the ice sheet, lakes were developed and into these sediments were being deposited by the adjacent streams. These bodies of water were usually non-marine and forms of animal life living therein were not numerous. Outside of the areas actually involved in these glacial lakes, glacial material was being deposited by retreating valley glaciers and the streams issuing from them. Such deposits are practically barren of animal life. Because of the character of deposition of all deposits formed, due directly or indirectly to glaciation, there existed no animal life which could possibly have acted as a source for petroleum deposits of commercial value. As a rule the deposits are soft and incoherent and the individual strata do not persist in character for any great distance. Even if small quantities of petroleum had been formed there would have been no means of preventing its escape. It is true there are present in many places very low grade lignite seams which might yield small amounts of gas, but a gas considerably different from that associated with petroleum. The glacial drift of western Washington may be regarded very unfavorable as the source or container for petroleum deposits.

PRE-GLACIAL FORMATIONS.

Beneath the glacial drift and in places extending up through it are sandstones, shales and lavas of Tertiary age. Their subglacial distribution is represented on the geologic maps accompanying this report. During the Eocene the entire Puget Sound region extending easterly into the Cascades was the site of extensive estuaries bordering on the marine waters of the ocean. In these bodies of water sediments consisting of sands, muds and clays were accumulating. Shorelines were shifting from time to time, allowing sediments of marine origin to become interbedded with those of purely estuarine origin. Sediments of the later type predominate throughout the Eocene. A careful examination of these strata fails to reveal the presence of any great quantities of fossil animal life. On the contrary there are extensive deposits of fossil plant life as attested to in the numerous coal seams occurring at intervals throughout the Eocene series. In the Puget Sound region, during the Eocene, conditions were not favorable for the development of marine animal life in sufficient quantities to act as a source for petroleum deposits.

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Throughout the Eocene volcanic activity was more or less prevalent. Interbedded with the sediments are extensive flows of andesites and basalts and accumulations of volcanic ash. These extrusive flows came to the surface through fissures rather than through great central volcanic cones. Some of the flows were apparently submarine.

After the close of Eocene time the sedimentary strata together with the volcanic material were uplifted and folded and then subjected to vigorous erosion. In King and Pierce counties post glacial erosion has cut down deeply into the old Eocene rocks, exposing over 10,000 feet of strata. Interbedded with the sandstones and shales are numerous coal seams. The whole series of strata have been thrown into sharply folded anticlines and synclines having a general north and south trend. The axes of these anticlines have been deeply dissected and if any petroleum deposits had been formed they would long ago have been destroyed. There is no evidence to warrant the supposition that oil has ever been present or is present today in the King and Pierce coal fields. Such gas as may be present may be directly associated with lignite deposits and cannot be connected with oil.

In Kitsap County, Eocene basalts outcrop in the hills west of Bremerton and south of Chico. Occasional layers of sandstone are interbedded but of no great extent. The igneous rocks could not possibly have been a source of petroleum and the sandstones which are interbedded are not of sufficient extent to act as a reservoir.

Oligocene strata of marine origin underlie the glacial drift of the northern portion of Puget Sound. They possess a thickness of nearly 10,000 feet and have been folded into anticlines and synclines. The southern limit of these outcrops is along a line extending from Seattle westerly to Bremerton and thence to Hood Canal. In places these strata contain fossil molluscan remains but not in large quantities. A careful search was made for diatomaceous deposits but none were detected. From such fossil life as formerly existed, petroleum

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in small amounts might have been formed. However, there are no direct indications of its having been present.

After the close of the Lower Miocene when folding took place, one prominent anticline was developed extending along the Newcastle Hills to Seattle and thence westerly to the Bald hills of Kitsap County. Along the north flank of this fold, numerous minor folds have been developed, all of which pitch to the north. To the north of this anticline, a syncline presumably extends parallel to it. Its northwestern continuation may be seen in Jefferson County south of Port Townsend. To the north of the syncline a second parallel anticlinal axis may exist but because of the great overburden of glacial drift it becomes impossible to definitely prove it. Along the Newcastle anticline, long continued erosion has cut down deeply so as to expose the core composed of Eocene basalts. From Seattle westerly across Kitsap County, the entire series of Miocene strata involved in the north limb of this anticline are standing nearly vertical, or with a steep pitch to the north. The truncated edges of the strata are exposed. Throughout this entire area any oil deposits which may formerly have existed must long ago have escaped. No impervious covering remains as a capping. The glacial drift which lies above in most localities is not sufficiently impervious to prevent its escape, and further these same strata were exposed as above described prior to glaciation. A similar condition appears to obtain farther north near Cathcart station and Snohomish. Southern Kitsap County and western Pierce County are so heavily covered with glacial drift that the geology of the older formations cannot be definitely determined. The character of the strata and the geologic structure which they now assume are such as to prohibit the accumulation and retention of petroleum deposits in commercial quantities in the Eocene and Oligocene formations of the Puget Sound Basin. There may be older formations of pre-Tertiary age lying beneath the Eocene which may be oil bearing or have been capable of producing oil at one time. Concerning such there is absolutely no evidence available. Any

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petroleum which may be present in the Eocene rocks has undoubtedly to a large extent seeped into them from such a source.

NORTH SLOPE OF THE OLYMPIC MOUNTAINS

From Cape Flattery eastward to Port Crescent and from the Strait of Juan de Fuca southward for a distance of approximately ten miles the floor upon which the deposits of glacial drift rest is composed of lower Miocene marine sediments. Beneath these are Eocene basalts, sandstones and shales which are exposed at Port Crescent but which are deeply buried below sea-level throughout the remainder of the area.

Deposits of glacial drift vary in thickness and mantle over almost the entire area of the district. Along the coast line and in the canyons of some of the streams the older rocks are exposed. The conditions under which the drift was deposited were approximately the same as in the Puget Sound Basin, and the possibilities for the occurrence of petroleum in the drift are extremely unfavorable.

The surface distribution of the Eocene is represented upon Plates II and IV. Exposures are well developed along the coast in the vicinity of Port Crescent. To the west the Eocene strata pass beneath Oligocene strata. Basalts and andesite constitute the major portion of the Eocene, although narrow bands of sandstone and shale are interbedded. Resting unconformably upon the Eocene are Oligocene and Lower Miocene marine sediments which in the Cape Flattery section attain a maximum thickness of nearly 19,000 feet. These strata in places contain numerous marine fossils. Alternating sandstone and shale bands are present. The whole series of Eocene and Miocene formations have been folded into anticlines and synclines and their approximate position has been indicated upon Plate IV. A synclinal axis extends from near Gettysburg southeasterly to Lake Sutherland. The entire series of strata including those of both Eocene and Oligocene age lying east of the position of the synclinal axis just mentioned are presumably dipping to the southwest and constitute one limb of

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the syncline. The strata on the western side of the syncline are dipping to the northeast. From the prevailing northwesterly dip of the strata west from Gettysburg there is direct evidence that they have been folded backwards, thereby developing an anticlinal fold. The exact position of this axis cannot be absolutely determined but its approximate position is fairly certain and has been indicated upon Map A, Plate IV, as extending from a point on the coast line a short distance west of Gettysburg southwesterly to the western end of Lake Crescent. From Twin westerly to Clallam Bay the Oligocene shales and sandstones have been thrown into numerous parallel folds whose axes have a prevailing trend of nearly north and south. The points where these axes intersect the coast line have been definitely determined, but their landward extension is only approximate. From Clallam Bay westerly to Cape Flattery the strata have a prevailing northeasterly dip and constitute a great monoclinal fold pitching away from the long spur extending from the Olympic Mountains west to the Point of the Arches.

East from Freshwater Bay the lower Miocene strata have been folded into a synclinal trough whose axis extends from the vicinity of Port Angeles southeasterly toward Quilcene. It may possibly be a continuation of the syncline existing north of Seattle. An anticlinal axis trends North 70° West from Port Ludlow to Port Discovery Bay but the overlying Oligocene sandstones and shales have been completely removed by erosion exposing the core of Eocene basalts and tuffs.

The following deductions may be made concerning the possibilities for the occurrence of petroleum along the north side of the Olympic peninsula:

1st—The formations involved consist of Eocene basalts, tuffs and sediments, together with an enormous thickness of Oligocene marine fossiliferous strata. The soft organic remains of life which formerly existed in the marine strata could upon slow distillation have produced petroleum products. The more porous sandstones which are present could have acted as reservoirs and the shale belts as impervious cappings.

2nd—The entire series of strata have been folded and if any petroleum deposits were formed they would tend to collect beneath the axes of the anticlines and those areas involved in the synclines would be barren. An inspection of Map A, Plate IV, will indicate the approximate position of the anticlines and synclines.

3rd—No direct indications of petroleum seepages have been seen by the writer in any portion of the area involved.

4th—The final conclusions may be drawn that on the north side of the Olympic peninsula geologic conditions are not such as to absolutely forbid the occurrence of petroleum deposits, although there are no direct indications to suggest their presence. If such deposits are present they will exist beneath the areas indicated upon the accompanying maps as anticlinal axes, where developed within the lower Miocene rocks. Those areas involved in synclinal folds should be considered as barren of possible petroleum deposits.

SOUTHWESTERN WASHINGTON.

GENERAL STATEMENT.

The more detailed description of the geologic and structural conditions obtaining in Southwestern Washington have already been presented in earlier chapters. The formations involved are of Tertiary age and are commonly covered with a very thick soil residuum or with Pleistocene deposits of gravel and sand. The entire Tertiary series is composed of interbedded sedimentaries approximately 15,000 feet in thickness. Whether petroleum is present in these formations or not has not as yet been demonstrated. In the volcanic rocks of the Eocene it cannot be expected to occur. If present at all in southwestern Washington it should be associated with the marine sedimentary phase of the Tertiary. For purposes of discussing the geologic and structural conditions in their relation to the possible occurrence of petroleum deposits in the southwestern portion of the state, it seems best to consider each county as a unit by itself.

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PACIFIC AND WAHKIAKUM COUNTIES.

The Eocene of these two counties is composed largely of basalts and basaltic tuffs, which constitute the backbone of the divide between the drainage leading into Columbia River and that into Willapa and Chehalis rivers. It forms a U-shaped area extending from the eastern part of Willapa Harbor southeasterly to the northern part of Wahkiakum and Cowlitz counties. From that point it turns due north. The character of the rock is unfavorable for petroleum deposits to originate within it or if originating without to accumulate within it. There may be strata below which are oil bearing but there is no evidence suggesting their occurrence. If such strata were present there would be no means of determining where the underlying reservoirs were situated. Those areas indicated upon the map of southwestern Washington in Pacific and Wahkiakum counties as Eocene may be regarded as unfavorable for the occurrence of petroleum deposits. (Plate III.)

The Oligocene formation in these counties is confined to two basins. The northernmost of these occupies the basin of Willapa River and the southern area extends east and west along the north side of Columbia River. The strata consist of sandstones and shales of marine origin and carry fossils. They have been folded into anticlines and synclines as previously described in chapters three and four and as designated upon the geologic map on Plate III. The only indications of petroleum which the writer has seen within these formations are some shales which give off a very decided odor of oil. They outcrop in isolated exposures in the hills between Bear River and the town of Ilwaco, in Sections 18 and 19, Township 10 North, Range 10 West. The shales are of a brownish gray color and when heated over a fire burn with a blue flame. An examination of the region indicates considerable faulting. Several basaltic lava flows are interbedded with the sedimentaries and also occur in the form of dikes. The region involved is worthy of a more careful detailed geologic examination and if in the future petroleum deposits are found to occur in commercial amounts they will undoubtedly be found to have originated in the Oligocene shales.

Whether the strata in other portions of these counties contain oil deposits is unknown. The strata are of such a character and have been folded into anticlines and synclines so that oil, if present, could accumulate. The total evidence from geologic data obtained is only sufficient to warrant the statement that petroleum may be present although no direct evidence to that effect is available.

GRAYS HARBOR COUNTY.

In the northwestern part of the county, in the Queniult Indian reservation, the Hoh formation is present and within that formation farther north oil in small quantities is definitely known to occur. A discussion of that portion of the county will be deferred until later. In the southern and eastern parts of the county, lower and upper Miocene rocks prevail. They consist of shales and sandstones all of which are of marine origin and fossil bearing. These strata have been folded and the position of the anticlines have been approximately inserted upon the geologic map. (Plate III.) No direct indications of petroleum have been seen within this area. Eocene basalts occur in the extreme eastern part of the county and are incapable of containing commercial oil deposits. The Miocene strata may possibly contain petroleum deposits. There is not now sufficient evidence to warrant the supposition that oil is present.

COWLITZ AND LEWIS COUNTIES.

The formations involved in the western part of these counties are of Eocene age and are composed of marine and brackish water sediments together with interbedded basalts and basaltic tuffs. The two latter are incapable of giving rise to or forming reservoirs for petroleum in commercial quantities. The brackish water strata contain no organic animal remains which would be capable of producing oil, although it might travel from some other source and collect in the coarse grained sandstones. The marine fossiliferous sandstones and shales could have pro-

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duced oil deposits but there is no evidence to prove that they have done so. The strata have been folded and the structure is such that oil, if present, might collect beneath the axes of the anticlines. Throughout this entire region basalts, marine and brackish water sediments are interbedded and if oil had ever formed in the marine sediments it might have collected either in the marine or in the brackish water strata. A large part of the western portions of these counties is covered with gravels and sands so that the older rocks do not appear at the surface. It is possible that if the strata were entirely exposed there might be seepages where faulting or fracturing had occurred. All that can be said concerning the possibilities for the occurrence of petroleum deposits in western Cowlitz and Lewis counties is that it could have originated in certain marine sandstones and could have accumulated beneath the axes of the anticlines, but no indications are available to suggest that such has been the case.

THURSTON COUNTY.

A large part of this county is covered with glacial drift and outwash gravels in front and south of the terminal moraine. The underlying bed rock where exposed consists of sandstones and lavas of Eocene age. On the areal geologic map accompanying this report those areas which are definitely known to be underlain with Eocene deposits are mapped as such. The areas mapped as glacial drift do not represent the entire area in which drift is present but rather those areas where it is so extensive that the character of the underlying rocks cannot be determined. In the Black Hills, in the western part of the county, basalts prevail and there can be no possibility for the occurrence of petroleum deposits within them. The outwash gravel plains in the central and southern part of the county are almost barren of trees and are covered with numerous small mounds which owe their origin absolutely to glacial causes. These are not gas mounds and have no relation to petroleum.

The sandstones where exposed are chiefly of brackish water origin and in places contain coal seams. The former organic

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life which existed in them was plant and not animal and hence could not have furnished fats which are the chief constituents of oils. The marine sediments, however, where present contain upper Eocene fossils and could have acted as a source for petroleum deposits. Where these are interbedded with the brackish water sediments, if oil were ever present it could have seeped into the latter. Interbedded with both brackish water and marine strata are basaltic lavas and tuffs. They apparently were laid down while the sanstones and shales were accumulating and hence would have but little effect upon any oil strata that might have been present. The whole series of Eocene strata have been folded and the positions of the anticlines and synclines have been plotted upon the geologic map (Plate III). There is absolutely no possible means of predicting whether oil deposits are present or not in this field. If they are present they will be found to have accumulated beneath the axes of anticlines and will occur in the more porous sandstones of the Eocene. The Miocene formations are not present as far as available evidence shows.

WESTERN SLOPE OF THE OLYMPIC PENINSULA.

The region from Grays Harbor northward to Cape Flattery is topographically an elevated plain bounded on the west by the Pacific Ocean and on the east by the Olympic Mountains. The surface of this plain ranges in elevation from one to five hundred feet above sea-level, but gradually increases easterly towards the Olympics. To the north it is terminated by the long axial spur extending out to Cape Flattery. The original surface has been deeply dissected by numerous rivers and creeks flowing across it and emptying into the ocean. The more important of these are the Queniult, Raft, Queets, Hoh, Bogachiel and Soleduck rivers.

The formations involved in this region are the Hoh, Montesano and Pleistocene gravels. The approximate distribution of these outcrops is represented upon the areal geologic map (Map A, Plate IV). The entire region is more or less deeply

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covered with Pleistocene sands, gravels, and clays, which rest unconformably upon all the older formations. During the Pliocene and prior to the deposition of the Pleistocene fluviatile deposits, the entire costal plain had been deeply dissected and depressed. Large rivers meandered over the surface and as time progressed large quantities of gravels and sands were dropped by these streams. These deposits lie nearly horizontal and range in thickness from a few feet to over 500 feet. Later the country was uplifted and the present streams have since cut down into those Pleistocene deposits and in places even into the older Hoh and Miocene formations. These older strata are generally exposed along the banks of the rivers and along the ocean cliffs.

The Hoh is the most extensively developed of the pre-Pleistocene formations on the western side of the Olympic Mountains. It possesses a thickness of at least ten thousand feet and is composed of massive and banded shales, conglomerates and extensive belts of shaly micaceous sandstones. The latter grade into a distinctly gray sandstone of medium grain which contains angular fragments of slate and of chert, and nearly always considerable amounts of micaceous shales. It is from this phase of the formation that the odor as well as seepages of petroleum are found. In places interbedded with this are soft brown to gray shales.

The Hoh formation has been folded into major and minor anticlines and synclines and the approximate position of these has been platted upon Map A, Plate IV. Insufficient work has been done to determine all the folds involved, but along the coast where exposures are generally well defined the structure has been worked out in detail.

Two prominent anticlines are believed to exist, trending north and south. One of these apparently lies in the floor of the ocean several miles off shore. The minor anticlines and synclines recorded along the shore may be folds developed in the east limb of this major anticline. It is believed that a second approximately parallel major anticline extends south from

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Forks in southwestern Clallam County, into Jefferson County. Such an anticlinal fold is definitely known to extend at least as far south as the north boundary of Jefferson County into Section 3, Township 27 North, Range 13 West. Its southward extension has not been traced. It is within this formation that petroleum indications on the west coast of the Olympic Peninsula are directly associated.

The upper Miocene strata are developed in the basin of Quillayute River in Clallam County and have already been described. No petroleum indications have been observed in the formation in this area.

In the region around the mouth of Queniult River, the strata of the upper Miocene or Montesano formation outcrop. They are exposed from a point about one mile north of Cape Elizabeth south to Point Grenville and for a distance inland of about six miles. Beyond, to the east, they presumably exist but are deeply buried beneath a very thick covering of Pleistocene gravels, sands and clays of fluviatile origin. Queniult River, except near its mouth, has not cut down through the Pleistocene to the Miocene rocks.

The region between the south boundary of the Queniult Indian reservation and Grays Harbor is covered with Pleistocene deposits but the Montesano series is believed to form the bed rock basement upon which they rest. In fact, where the Humptulips and Wishkah rivers cut down to bed rock the upper Miocene strata are exposed. With the exception of certain localities at Cape Elizabeth no petroleum indications are known to occur in the formation in this region.

The Pleistocene deposits are devoid of petroleum. At various places gas is reported to arise from swamps lying in these deposits. Upon examination such gas is found to be chiefly methane, derived from decaying vegetable remains in buried swamps. Occasionally iron oxide appears as a coating on the small pools upon the surface of these gravels and sands. It forms an iridescent coating on water very close in appearance to that of oil.

The areal distribution of the Hoh formation is indicated upon Map A, Plate IV. Seepages of oil have been found in a few places. Gas has been found in a number of places. Many localities abound where the odor of petroleum can be detected sometimes at some distance from the outcrop; at other times only when the rock is freshly broken.

SOURCE OF THE PETROLEUM.

No fossil molluscan remains have been found within the Hoh formation. Locally small pockets of carbonaceous shale occur. A microscopic examination of the shales and shaly sandstones shows the presence of large numbers of diatoms. These are not present in sufficient numbers to form a cherty diatomaceous shale, yet in some specimens of shale they are closely packed. Samples collected from the Hoh Head shales revealed the presence of large numbers of these forms of life. In the well at Forks, shale brought up from a depth of 1800 feet, shows the presence of numerous foraminifera. Chemical examinations made of living marine diatoms show the soft organic parts to be composed of organic compounds of a position closely related to that of petroleum.

In the western Olympic region there appears to be no source except from diatomaceous or foraminiferal remains from which such petroleum deposits as occur could have been derived. The scattered areas of Miocene strata are too limited to have been the source. In other regions in the state where the Miocene deposits are more extensively developed no indications of petroleum are known. The rock formation underlying the Hoh formation is unknown. All the older formations in the northwest have been extensively metamorphosed and the probabilities are that such rocks as underlie the Hoh are in that condition. If so, they could hardly supply the organic material. The fact that considerable quantities of diatoms and foraminifera are present in certain portions of the Hoh formation and that it has been demonstrated in other regions that petroleum compounds may have been derived from such sources and further that no other sources in this region are present, indicates that

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the petroleum products in the Hoh formation are probably derived from these organisms. The Hoh formation is the only one in the state from which definite evidences of petroleum are known.

There are massive brown sandstones in the formation which could act as retaining reservoirs provided some impervious capping were present. Such reservoirs would be expected to form beneath the axes of the anticlines. Whether such deposits occur in commercial quantities or not can only be determined by drilling on the axes of the anticlines in this formation.

GEOLOGIC CONDITIONS IN SPECIAL AREAS ON THE WEST COAST OF THE OLYMPIC PENINSULA.

Bearing in mind the fact that very small amounts of petroleum are known to occur in the Hoh formation and further that its occurrence in commercial quantities has not been proven, it is possible that petroleum might occur anywhere within the formation provided structural conditions are favorable. In order to fully discuss these conditions, the western portion of the Olympic Peninsula has been separated into districts for description, as follows: Southwestern Clallam County, Ozette Lake Region, Western Jefferson County, and the Queniult Indian Reservation.

SOUTHWESTERN CLALLAM COUNTY.

The area involved in this district embraces Township 28 North, Ranges 14, 13 and part of 12 West. It extends from the ocean on the west to the Olympic Mountains on the east. It is drained by the Soleduck, Calawah and Bogachiel Rivers. The average elevation is 500 feet above sea level, with an increase from west to east.

With the exception of a small area near the forks of the Soleduck and Bogachiel rivers which is upper Miocene, the entire areal geology consists of outcrops of the Hoh formation. Outcrops of this formation appear at intervals along the cliffs of the Bogachiel and Calawah rivers and also in the more highly elevated divide between those rivers in the eastern part of the region under discussion. (Plate XI.) The strike and dip of

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the strata at these points have been platted upon this map. All observations taken in the eastern half of Township 28 North, Range 13 West, show a pronounced easterly dip ranging from 35° to 88°. In the western half of this same township and range the strata are dipping to the west from 50 to 60 degrees and continue to do so towards a synclinal basin in the eastern half of Township 28 North, Range 14 West. A well defined anticline crosses Bogachiel River near the boundary between Sections 33 and 34, Township 28 North, Range 13 West. From observations taken to the east and west it apparently extends northerly through Sections 28, 21 and 16 of the same township and range to the town of Forks. To the south it passes into Jefferson County in Section 3, Township 27 North, Range 13 West. This fold for purposes of reference will be designated as the Forks anticline.

A well defined syncline trends nearly north and south through Sections 12, 23, 26, and 35, Township 28 North, Range 14 West. In the western half of this township the Montesano formation rests nearly horizontal upon the steeply dipping truncated edges of the Hoh strata.

Indications of gas and the odor of petroleum occur at intervals along Bogachiel and Calawah rivers. The odor of petroleum is particulaly noticeable in the shaly sandstones in the northeast 1/4 of Section 23, Township 28 North, Range 14 West. In Sections 20 and 34 on Bogachiel River and Section 3 on Calawah River, Township 28 North, range 13 West, the rock has a decided odor of petroleum when freshly broken and may be noticed for some distance away as one approaches these localities. In Section 27, Township 28 North, Range 14 West on Bogachiel River the sandy shales have weathered into a bluish gray mud. A very noticeable odor of natural gas can be detected. Several small holes made with a pick handle allow the gas to escape with a sizzling sound. When lighted it will burn in each case for about one minute with a blue flame. A well is being bored by the Washington Oil Company of Seattle in

Section 16, Township 28 North, Range 13 West, south of the town of Forks on Forks Prairie.

QUENIULT RIVER DISTRICT.

The area involved in this district extends from Grays Harbor northward to Queets River and includes the Queniult Indian Reservation. The entire region is an uplifted plateau-like bench with an undulating surface and ranging in elevation from 100 to 400 feet. Along the ocean shore line the cliffs extend from sea level to two hundred feet in elevation. The formations are almost exclusively of sedimentary origin. The only exception is a small patch of basic lava with intercalated sediments at Point Grenville whose age cannot be definitely determined except that it is pre-Miocene. The larger part of the region is covered with horizontally bedded Pleistocene gravels and sands. Along the sea coast and in those places where the rivers have cut down through the gravels the older formations are exposed.

The Hoh formation undoubtedly underlies the younger formations of this entire region but it is exposed at the surface only near the mouth of Queniult River. It outcrops in the cliffs along the ocean in the northwest ¼ of Section 27 and the southwest ¼ of Section 22, Township 22 North, Range 13 West. The exposures extend along the cliff for a distance of about 1500 feet. To the south and possibly also to the north, they are terminated by a fault. The entire exposure is involved in a slide and badly crushed. It is largely composed of brown chocolate colored shales with narrow intercalated layers of sandstone which assume a general strike of North 45° West and a dip of 35° to the northeast.

In the southeast ¼ of Section 6, Township 21 North, Range 12 West on the south side of the big bend in Queniult River there is an outcrop of shale involved in a big slide which has been largely converted over into a bluish gray mud. The shale is of a chocolate brown color and closely resembles that occurring to the northwest along the ocean bluffs. It has been so badly crushed that no strike nor dip could be obtained. Its eastern limits are determined by a well defined fault. The sur-

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face between these two localities is heavily covered with gravel and sand, and it cannot be definitely stated that the Hoh shales occupy the intervening area as has been indicated upon the map. The fact that these faults are of considerable size and approximately in line indicates that the Hoh shales probably extend through as a fault block. These are the only surface exposures of the Hoh formation within the area examined and they undoubtedly underlie unconformably the entire area.

Upper Miocene conglomerates and sandstones constitute the formations exposed along the ocean cliffs from Queniult River northward to a point one and one-half miles above Cape Elizabeth. They form the Cape Elizabeth fault block which in itself does not seem to be badly broken. A detailed stratigraphic section has been measured and has been inserted in chapter five. The strata as here exposed strike northeast and southwest and dip at a low angle to the southeast. In the east central portion of Section 34, Township 22 North, Range 13 West, they are slightly folded into a monocline. The axis extends inland in a northeasterly direction.

In the northwest 1/4 of Section 35, Township 22 North, Range 13 West, a gas mound is situated approximately upon the axis of this monoline. It is located a few hundred feet west of the horse trail on the top of the plateau. It has a diameter of about 200 feet and a height of 50 feet, and seems to have been built upon the surface of the low plain. It has existed for some time as large trees are growing upon it. At the summit there is a large crater about four feet in diameter, filled with water and surrounded with mud which is continually issuing forth. Large bubbles of gas almost continuously escape, which when lighted burn with a blue flame. About 100 feet north, on the side of the same mound, there is a smaller gas spring. This mound is located 200 feet above the level of the river and could not reasonably arise from swamp or decayed vegetation which has been buried on the river flat. The gas is probably derived from some depth in the bed rock.

The Hoh formation undoubtedly exists at a considerable distance below the surface. To the north in Jefferson county, gas is very commonly associated with the latter. It is quite probable that the gas issuing from the mound owes its origin to that source; that it has seeped upward into the Miocene sandstones and shaly sandstones and has accumulated in pockets along the axis of the monocline and at the point where the mound has been built up, escapes to the surface. If that be the case, and it seems most probable, it would be impossible to determine at what depth pockets might occur, or how large they might be. The character of the upper Miocene sandstones would allow pockets to form at various depths.

If the gas is of the same origin as that in the Hoh formation farther north, it is possible that oil is associated with the Hoh strata below, but whether in commercial quantities or not there is no possible means of predicting.

QUEETS RIVER DISTRICT.

Topographically this district as in the case of Queniult district farther south is an uplifted plain which has been cut into by Queets River. The entire region is heavily timbered and the surface covered with dense thickets of underbrush. In places it is swampy. The tide extends up Queets River for about one and one-half miles. Three formations are represented within this district. The older is the Hoh and it is important because farther to the north it is the formation with which indications of petroleum are associated. In places above this are shales and sandstones of Miocene age. Resting unconformably upon both the Hoh and Miocene formations are extensive deposits of gravels, sands and clays of Pleistocene age. The latter were deposited by rivers which formerly meandered across this region when it was at a much lower elevation than at present. After uplift the present streams endeavored to cut their channels down through it. In many places they have succeeded as may be seen in the banks of Queets River and in places on Salmon Creek. The general character of these formations has already been described in chapters two, five and six.

All of the actual pre-Pleistocene rock exposures along Queets River and Salmon Creek belong to the Hoh formation. No seepages of petroleum were seen and no odor detected at any point. However, the formation as exposed here is a continuation of that outcropping along Hoh River, where indications of petroleum are present. Miocene strata are exposed along the coast near the mouth of Raft River. The older Hoh formation was folded and eroded prior to the deposition of the Miocene strata.

The data from which it has been possible to determine the principal structural features of this region have been inserted upon Map A, Plate IV. In certain localities the structure is well defined; in other localities it has been generalized from the better known structural conditions some distance away. In those localities which are covered with Pleistocene deposits it is impossible to say absolutely just what the bed rock structure is beneath. Strikes and dips have been recorded at every possible place along Queets River and on Salmon Creek. Along the Queets the prevailing structure shows a general north to south strike and an easterly dip. In places this strike swings westerly and easterly. All of the outcrops of the bedrock formation on the Queets are of the Hoh formation and it is certain that these strata underlie the entire central and southern part of the area involved in the district.

On Salmon River, in Sections 35 and 36, Township 24 North, Range 12 West, there is a high rocky ridge which has been cut into by stream action. The river flows through two gorges, one on the northwest and one on the southeast side of the big bend in the river. On the northwest side the prevailing strike is North 60° East with a dip of 50° to the northwest. On the southeast bend in the second gorge, the strike is North 30° West with a dip of 25° to the southeast. For a distance of two miles farther up the river this southeasterly dip prevails.

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There is direct evidence here that an anticline trends northeast and southwest.

To the north on Queets River, above the junction with Salmon River, the strata are dipping to the northeast and to the east, giving direct evidence of a synclinal axis trending northeast and southwest. Its probable position has been indicated upon the map. Both the anticlinal and synclinal axes, in their southwesterly continuation, pass beneath a thick covering of Pleistocene gravels, sands and clays. It is probable, however, that they tend to merge, and in the area involved in Sections 1, 2, 3, 10, 11, 12, 13 and 14, Township 23 North, Range 13 West, possess a comparatively flat attitude with a low dip to the east.

A minor anticlinal axis exists just south of the mouth of Queets River. It trends about North 40° East. The evidence for this anticline has been obtained from strikes and dips taken around the cliffs in the big bend in the river. It is undoubtedly a minor warp or dome, or spur, on the eastern limb of a large north and south anticline whose main axis lies parallel to the coast line and probably not far from the shore. The eastern limb of this minor anticline has a comparatively low dip to the southeast. The strata are composed chiefly of interbedded sandstones and shales. The axis lies on the low flat ground in the bend in the river and probably extends out toward the shore.

Concerning the possibilities for the occurrence of petroleum deposits within this district the following statement is made: The Hoh formation which contains small seepages northward in Clallam and Jefferson counties is the bed rock formation in this region. No actual seepages, however, have been seen within the strata along Queets River. The strata have been folded into anticlines and synclines as have already been described. Altogether they have a thickness of at least 5,000 feet. There is no possible means of determining whether petroleum deposits occur in commercial quantities or not except by drilling in those localities along the axes of the anticlines. If it should be present there is no means of determining how deep it would

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be necessary to drill to reach it. Such deposits as might occur would probably be derived from the shales of the Hoh formation.

HOH RIVER DISTRICT.

The region involved embraces nearly all of western Jefferson County. The major portion of the area is thickly covered with Pleistocene sands and gravels. The bedrock exposures are well developed along the coast line and at intervals along the banks of Hoh River. The detailed examination of the region has been confined to the coast about Hoh Head and the lower part of Hoh River. The more important structural features may be seen by referring to Map A, Plate IV, and also to Plate XII. The interior region has not been examined in sufficient detail to warrant a statement concerning structural conditions.

Near the mouth of Hoh River several smaller creeks have carved out low valleys extending to the river. The highest elevations are less than three hundred feet. The region is heavily timbered and is bordered on the ocean in most places with bold cliffs. There is a broad cove in Section 12 just south of Hoh Head. The land area just back from shore is composed of slide rock in a badly decomposed condition. Hoh Head is a bold rocky point jutting out into the ocean. Between the two points of this head there is a narrow cove. The rock formations in back of this cove are composed of sandy shale and shale all of which are involved in a slide.

There are two formations outcropping in this region. The older is designated as the Hoh and the later as Pleistocene gravels, sands and clays. The Hoh formation is composed of sandstone, shale and conglomerate. The total thickness of this formation, as represented on the western side of the Olympic peninsula, is over 10,000 feet. Within the area of this district only a part of this formation outcrops at the surface. Sandstones and shales occur in equal amounts. The sandstones are massive, generally coarse grained, brown, and only occasionally are shale bands or bedding planes present so as to determine the strike and dip. In places they gradually grade into con-

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glomerates. The shales are generally gray to chocolate colored. They often grade into sandy shales and these in turn into shaly sandstones. The shaly sandstones very often become massive and when freshly broken are seen to be composed of angular fragments of slate and quartzite. They possess a gritty appearance but are sometimes banded. The bands are made up of scales of mica and fragments of dark heavier minerals. Sandstone of this character seems to be interbedded with the shales and sandy shales in all localities where the Hoh formation outcrops. The sandy shales and shaly sandstones weather much more rapidly than the belts of massive sandstone and are commonly involved in slides. Ultimately this material passes into a bluish gray mud. It generally possesses a distinct odor of petroleum and in several places yields seepages of it. A careful examination of specimens of the shale reveal the presence of microscopic diatoms.

Within the area of this district there is one very well defined anticline trending northeasterly and passing through the southeast 1/4 of Section 12. The north limb of this anticline is well represented in the south point of Hoh Head by massive sandstones striking North 30° East and dipping 80° northwest. One half mile to the southeast, at Rocky Point, massive sandstone forms the southeastern limb of the anticline. Between these two points the formation is composed of shale, sandy shale and shaly sandstone, badly involved in a slide. These shales have a very pronounced odor of oil. The massive sandstone at Hoh Head originally arched over this anticline and connected with the sandstone and conglomerate on the south side. This has since been removed by erosion. The axis of this anticline passes out into the cove as indicated upon the map. Near its trend inland several pits have been sunk. One of these is eighteen feet deep. From its walls oil is slowly seeping into it. All the strata in the near vicinity give a pronounced odor of petroleum.

A second small anticline enters the north side of Hoh Head from the northwest and trends South 60° East. It seems to die

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out before crossing Hoh Head. A third anticline possibly crosses the mouth of Hoh River into the northeast 1/4 of Section 19 but because of lack of good exposures its exact extent cannot be determined. Its probable position has been indicated upon the accompanying map. A syncline extends from the center of Section 13 northeasterly but its extent cannot be determined. Another syncline enters the north point of Hoh Head from the ocean. It trends South 75° East and dies out before crossing the peninsula. A minor syncline is developed in the cove between the south and north points of Hoh Head. It is possible that this may swing and pass north into the cove on the north side where the trail comes down to the beach.

Examinations of this district show that petroleum and gas are present in very small quantities but whether they exist in commercial amounts or not has not been demonstrated. If they are they should be sought for beneath the anticlinal axes.

QUILLAYUTE RIVER DISTRICT

The area involved in this region comprises the valley of Quillayute, Bogachiel and Soleduck rivers. It embraces parts of southwestern Clallam and northwestern Jefferson counties. Topographically the district is similar to that to the north in the vicinity of Ozette Lake and to the south towards Grays Harbor. With the exception of a small area near the junction of Bogachiel and Soleduck rivers, which is upper Miocene all of the preglacial formations belong to the Hoh. The general character of the sandstones and shales have already been described in chapter two. The structural data may be referred to on Plate XI. The interpretation of this data when platted indicates the presence of two anticlines and one syncline in which the strata of the Hoh formation are involved. The axes of these folds have a general north-south to northwest-southeast trend. Their approximate position may be referred to upon Plate XI. The axis of the western anticline trends northwesterly parallel to the coast from Hoh River and then swings to the north and passes inland in Section 1, Township 27 North, Range 15 West. The eastern anticline trends southerly in Township 28 North,

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Range 13 West, through Sections 2, 11, 16, 21, 28 and 33 into Jefferson County. The axis of the syncline trends southerly through Sections 23, 26 and 35, Township 28 North, Range 14 West. The axis of the syncline is best indicated in the outcrops along Bogachiel River from the northwest 1/4 of the northwest 1/4 of Section 24, Township 28 North, Range 14 West, to a point about one mile westward down the river. The western anticline should cross Quillayute River near the western boundary of Township 28 North, Range 14 West, about one and one-half miles below the junction of Soleduck and Bogachiel rivers. This conclusion has been arrived at from the projection of the strata inland in accordance with the strike and dip along the coast. The axis of the eastern limb involves the strata in the eastern part of the township forming the eastern boundary of Forks Prairie and underlies the prairie. On the headwaters of Elk Creek, Calawah River and Bear Creek the dip of the strata is easterly. On the western side of Forks Prairie, the surface of the country is low and flat and outcrops of bed rock strata are absent except in places along the banks of Bogachiel River. There the prevailing strike is north and south with a westerly dip. Where the axis of the anticline should cross Bogachiel River in Section 34, Township 28 North, Range 13 West, the sandstones indicate a nearly vertical dip and north to south strike and possess in places an odor of petroleum.

That portion of the formation represented on the surface near the axis of the western anticline is apparently deeply buried along the eastern axis. Whether oil is present in commercial quantities can only be determined by boring upon the axis of one of the anticlines indicated upon one of the accompanying maps of the region. An examination of shales encountered in the well which is being bored by the Washington Oil Company at Forks indicates the presence of numerous species of foraminifera and it is presumably from these organisms that such gas and oil seepages as are present, were originally derived.

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OZETTE LAKE DISTRICT.

The area involved in this district occupies Townships 29 and 30 North, Ranges 14 and 15 West. It embraces a belt about twelve miles in width and fifteen in length bordering the coast. It extends from Quillayute River northward to the axial spur extending from the Olympic Mountains outward toward Cape Flattery. The region is densely covered with timber. The surface formations are largely composed of glacial deposits or a very thick veneer of soil. Along the coast the sandstones and shales of the Hoh formation are exposed. Inland they appear at only a very few localities in the cliffs or along the river channels. The later Miocene strata which outcrop both to the south and to the north are absent in this district. The Hoh formation has been folded and the position of the anticlinal and synclinal axes have been inserted upon Map A, Plate IV. The character of the strata has been described in chapter six.

Wherever the gray shaly sandstones outcrop along the coast from the mouth of Quillayute river north to the Point of Arches there is usually a well defined odor of petroleum. In places a white scum issues through cracks and possesses an odor of oil. There is no means of predicting whether oil is present in commercial quantities or not. If present it will presumably occur beneath the anticlinal axes and will be absent along the synclinal troughs. Along the coast line the positions of the anticlinal axes are fairly accurate but inland insufficient data has been obtained to determine the structure. The formation involved, however, is the Hoh with which petroleum indications elsewhere are associated.

CONCLUSIONS.

There seems to be sufficient evidence to warrant considering all of the Cascade Mountains as an extremely unfavorable region for the occurrence of petroleum deposits. In the western part of the state all areas where the formation is composed of basaltic lavas or of metamorphic rocks the same condition prevails. On the north slope of the Olympic Mountains, and in

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most parts of southwestern Washington, there are formations present which might possibly contain petroleum deposits although there is no evidence at present available to directly suggest that they are present. On the western slope of the Olympic peninsula there are several small seepages of oil and gas and numerous localities where the odor of oil may be detected. The strata have been folded and oil may occur beneath the axes of the anticlines although it is impossible to determine whether it occurs in commercial quantities or not. Many so called oil seepages reported as occurring in other parts of the state consist only of a scum on water due to decaying vegetation. The gas which often is noted as issuing from pools of water is common marsh gas which is due to the presence of decaying vegetation.

RECORD OF DRILLING OPERATIONS.

COPALIS WELL.

In 1901 a well was drilled by the Olympic Oil Company, which is now out of existence, near the mouth of Copalis River, in Grays Harbor County. This well is reported to have been drilled to a depth of 850 feet and to have encountered very small amounts of oil and gas at several depths. The surface exposures of rock in this region are almost entirely composed of Pleistocene sands and clays. At Copalis Rock, on the beach, gray sandy shales outcrop at the water's edge and appear very similar to the sandy shales and shaly sandstones of the Hoh formation farther north. On account of a crooked hole the well was abandoned. During the same year a well was drilled in the same region by the Eldorado Oil Company to a depth of 350 feet and is said to have passed through sandy shale for the entire depth. No oil was obtained but a flow of artesian water was encountered.

LA PUSH WELL.

The following year a well was drilled by the La Push Oil Company to a depth of 550 feet. The derrick is still standing, but operations ceased later in the same year that drilling began. The well is situated about three miles south of the mouth of

Quillayute River and one-half mile inland from the shore. The formation in this region is composed of Hoh shales and sandstones.

FORKS PRAIRIE WELL.

This well is located in the southeast quarter of Section 9, Township 28 North, Range 13 West, about one mile south of Forks Post Office and two miles north of Bogachiel River in Clallam County. Drilling began in the autumn of 1912 and in December, 1914, the well had reached a depth of 2,050 feet. Gas and small amounts of oil were encountered at several depths. The strata as exposed in the outcrops in this region are a part of the Hoh formation. The well is being sunk upon the axis of an anticline trending nearly north and south. In a number of localities in the near vicinity of the well the strata yield a decided odor of oil and emit small quantities of gas. Gas and small amounts of oil were said to have been encountered at several depths as the well was being sunk. The machinery consists of a standard rig operated by steam power. Boring was started with a 16-inch casing and continued to a depth of 100 feet. The following statement is the record of casing used in this well:

100 feet 16-inch.
300 feet 12½-inch.
1062 feet 10-inch.
1550 feet 8-inch.
1980 feet 6¼-inch.

HOH HEAD WELL.

This well is situated in Section 12, Township 26 North, Range 14 West, about two miles north of the mouth of Hoh River in western Jefferson County. The formation in this vicinity consists of shales and sandstones of the Hoh formation which have been folded into anticlines and synclines. The Hoh Head well is being drilled on the axis of a northwest to southeast anticline immediately south of Hoh Head. Drilling was begun in September, 1913, and continued to a depth of 901 feet. The following log has been furnished by the Jefferson Oil Com-

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pany. Wherever the term slate is employed it presumably refers to a hardened shale.

	Feet
Mud	9
Sand	5
Shale	23
Shale	17
Sand	5
Shale and sand	5
Shale	20
Sand	5
Shale	5
Shale and sand	5
Shale	35
Shale and sand	5
Shale	25
Sand	3
Shale	37
Sand	3
Shale	7
Sand	4
Slate	26
Sand	5
Slate	20
Slate and sand	5
Slate	15
Sand and slate	20
Slate	16
Sand (little gas)	3
Slate	26
Sand (gas)	2
Slate	38
Slate	40
Slate	5
Sand and slate	86
Hard sand	5
Sand and shale	86
Hard shale	14
Shale	11
Sand	8
Shale (big showing of gas)	14
Sand	14
Shale	9
Sand and shale (heavy gas)	5
Sand (oil and gas)	105
Sand and shale	40
Sand	15
Sand and shale	40
Sand (very heavy gas)	10
Total	901

On June 30th, 1914, a second well was started a short distance from well No. 2. Up to the present time this well has been sunk to a depth of 986 feet. The strata passed through was similar to that encountered in well Number 1. The following is a list of the casing used:

44 feet 18-inch.
78 feet 15½-inch.
331 fee 12½-inch.
376 feet 10-inch.
766 feet 8-inch.
986 feet 6-inch.

This property has been operated by the Jefferson Oil Company of Aberdeen.

QEUNIULT WELL.

Immediately north of the mouth of Queniult River and south of Cape Elizabeth in Section 35, Township 22 North, Range 13 West a well was drilled by the Indian Oil Company. The formation involved in this region is the Montesano or upper Miocene. Just south of Cape Elizabeth a minor flexure in the form of a monoclinal fold extends northeast and southwest. On the surface of the bench at an elevation of about 250 feet a mound has been built up and at the apex of the mound there is a small crater filled with water from which gas is continuously bubbling forth. Within a few feet of the apex a well has been sunk to a depth of over 500 feet. In October, 1914, a new well was started near by and was sunk to a depth of 458 feet. The well was started with 10-inch casing. The machinery consists of a rotary rig operated by steam power.

WILLAPA WELL.

This well was drilled by the Willapa Harbor Oil Company near the town of Raymond, Pacific County. The formations encountered consist of shales and sandstones of Oligocene age. Drilling was begun on August 29th, 1914, and on October 17th of the same year a depth of 1,445 feet had been reached. The following log has been reported by the company:

	Feet
Clay soil	6
Clay and sandstone	34
Dark shale	1005
Sand with indications of oil	6
Shale	344
Sand with shells	50
Total thickness	1445

Drilling was started with ten-inch casing and continued with such to a depth of 350 feet. From the 350-foot level $8\frac{1}{2}$-inch casing was used to a depth of 1,154 feet. Below that depth $6\frac{1}{4}$-inch casing was employed.

CHICO WELL.

This property is owned by the Kitsap Oil and Development Company of Bremerton, Washington, and is located in Section 5, Township 24 North, Range 1 East, near Chico, in Kitsap County. Drilling was begun in December, 1913, and in December, 1914, a depth of 1,408 feet had been reached. A standard rig with hydraulic circulator was used and operated by steam power. Use was made of the following sized casings: $12\frac{1}{2}$-inch for the first 170 feet; 10-inch for the next 450 feet; 8-inch for the following 875 feet and 6-inch for the remainder.

This well was drilled on the north flank of the Newcastle anticline. The surface formations are composed of glacial drift. Below the drift are steeply tilted sandstones and shales of the middle Oligocene formation. No log is available for use in this report.

BALLARD WELL.

This well is located in Ballard in the northwestern part of Seattle. The surface formations are composed of very thick deposits of glacial drift which are presumably underlain with shales and sandstones of Oligocene age. In December, 1914, the well had been drilled to a depth of 1,700 feet. The well was started with 15-inch casing and later reduced to 12-inch, 10-inch, 8-inch and finally $6\frac{1}{4}$-inch casing. A standard rig was installed and operated with oil for fuel.

PACIFIC STATES WELL.

This property is located in Section 15, Township 15 North, Range 3 West, in Thurston County. Drilling was started in April, 1914, by the Pacific States Oil Company, and in December, 1914, a depth of 750 feet had been attained. Operations began with a Number 27 Star rig, but later a standard

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rig was installed. The well was started with 12-inch casing and at the present level a ten-inch was employed.

OILFIELD WELL.

This property is owned by the Home Oil Company of Seattle and is located in King County in Section 12, Township 34 North, Range 5 East. Drilling was begun in November, 1914, and in January of the following year a depth of 316 feet was reported. The well was started with 12-inch casing and a Keystone rig. The geologic formation in this region is the estuarine phase of the Tejon Eocene but the surface deposits are composed of glacial drift. The Eocene sandstones and shales are a part of the south limb of the Newcastle anticline.

APPENDIX.

FAUNAL LOCALITIES IN WESTERN WASHINGTON.*

1

One and one-half miles east of Vader, Lewis County, on the west bank of Cowlitz River in massive sandy shales of marine origin, situated in Section 27, Township 11 North, Range 2 West. Tejon series, upper Eocene. Old locality 3003.

2

On Olequa Creek about one mile above the junction of Olequa and Stillwater creeks, back of the old Cantwell place, in Section 29, Township 11 North, Range 2 West. Tejon series, upper Eocene. Old locality 3002.

3

On a small creek about one third mile from its junction with Brinn Creek, under an old bridge, in Section 25, Township 11 North, Range 3 West. Tejon series, upper Eocene. Old locality 3001.

5

In Lewis County at a ledge just above the junction of Olequa and Stillwater creeks at Vader in Section 32, Township 11 North, Range 2 West. Upper Eocene. Old locality 3004.

6

In Lewis County one mile west of junction of Stillwater and Olequa creeks on the former in Section 30, Township 11 North, Range 2 West. Upper Eocene, Old locality 3005.

7

On Coal Creek, Cowlitz County, one and one-half miles north from Inman Poison Logging Company's store.

8

In Coal Creek, Cowlitz County, one mile north from Inman Poison Logging Company's store, in brackish water shales, in Section 35, Township 9 North, Range 3 West. Old locality 3007.

9

In Northern Pacific Railway cut one hundred feet east of Seattle Brewing & Malting Company's brewery at Georgetown, South Seattle, in Section 20, Township 24 North, Range 4 East. Oligocene. Old locality 3008.

10

About one thousand feet south of Alki Point, West Seattle, in Oligocene shales outcropping at the water's edge in Section 15, Township 24 North, Range 3 East. Old locality 3009.

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* From Tertiary Faunal Horizons of Western Washington, University of Washington Publications in Geology, Vol. 1, No. 1, pp. 8-22.

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11

At northeast corner of rock outlier at Duwamish station in Section 10, Township 23 North, Range 4 East. Tejon series, upper Eocene. Marine sandstone. Old locality 3010.

12

In Northern Pacific Railway cut one-half mile north of Cathcart Station, Snohomish County, in Section 6, Township 27 North, Range 6 East. Locally known as Fiddlers Bluff. Oligocene. Old locality 3011.

13

In marine sandstones on north side of Restoration Point, Kitsap County, opposite Seattle, in Section 12, Township 24 North, Range 2 East. Oligocene. Old locality 3012.

14

On the south fork of Ostrander Creek two hundred feet south from a point where the logging road crosses, which is 1130 feet from the town of Ostrander. In Section 12, Township 8 North, Range 2 West, in brackish water upper Eocene shales.

18

In Cowlitz County in Coal Creek 6500 feet up creek from Inman Polson Logging Company's store. In section 35, Township 9 North, Range 3 West. Upper Eocene. Old locality 135.

20

In Cowlitz County 13,000 feet up Coal Creek from wagon bridge crossing. Upper Eocene. Old locality 136.

21

In Cowlitz County 14,000 feet up Coal Creek from wagon bridge crossing. Upper Eocene. Old locality 137-B.

22

On east side of Ilwaco Point in Section 4, Township 9 North, Range 11 West, in shales which are interbedded with basalts. At traverse station 32.

23

In bluff on north side of Columbia River one-half mile east of the town of Ilwaco in Section 34, Township 10 North, Range 9 West. Probably Oligocene.

24

At Knappton, Pacific County, on north side of Columbia River in bluff back of cook house of Knappton Lumber Mill in Section 8, Township 9 North, Range 9 West. Oligocene. Old locality 139.

25

In Pacific County in bank of Nasel River two and one-half miles east of the town of Nasel in Section 11, Township 10 North, Range 9 West. Oligocene. Old locality 140.

27

In Pacific County 700 feet up Alder Creek from its junction with the east fork of Nasel River in Section 15, Township 11 North, Range 8 West, in a fine dark colored tuffaceous shale interbedded with tuffs and basalts. Oligocene. Old locality 151.

28

In Pacific County 12,000 feet up Hull Creek from the hotel at town of Gray's River in Section 6, Township 10 North, Range 7 West. Oligocene. Old locality 154.

29

In Pacific County 15,000 feet up Hull Creek from the hotel at town of Gray's River in Section 6, Township 10 North, Range 7 West. Oligocene. Old locality 155.

30

Sea cliff between Point Grenville and Taholah in Section 13, Township 21 North, Range 13 West. Upper Miocene.

31

In railway cut, O.-W. R. R. & N. Co., one-half mile west of Lincoln Creek Station, Lewis County, in Section 36, Township 15 North, Range 3 West. Oligocene. Old locality 181.

32

West of the county wagon bridge over Lincoln Creek in sandy shale, near Lincoln Creek Station. Old locality 180.

33

Six thousand feet east of Heising Junction on the O.-W. R. R. & N. Co. in Thurston County. Eocene. Old locality 182.

34

In Pacific County on Grays River two miles beyond its junction with Blaney Creek in Section 19, Township 11 North, Range 6 West, in a dark tuffaceous shale. Oligocene. Old locality 158.

35

In Pacific County on Nemah River at wagon bridge crossing, four miles east of Nemah post office in Section 33, Township 12 North, Range 8 West. Shales interbedded with basalt. Old locality 167.

36

Exposure at old wagon road trestle along Willapa River at the town of Willapa. In Section 22, Township 14 North, Range 7 West. Oligocene. Old locality 170.

37

In Pacific County at Northern Pacific Railway bridge below Lebam Station in Section 6, Township 12 North, Range 7 West. Oligocene. Old locality 175.

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38

At bridge over Chehalis River northwest of Pe Ell station at power station in Section 34, Township 13 North, Range 5 West. Old locality 176.

39

One mile northwest of Pe Ell station in Lewis County on west side of Chehalis River, in Section 33, Township 13 North, Range 5 West. Old locality 177 A.

40

In Northern Pacific Railway cut 67 miles north of Portland.

41

In bank of small creek below Booth's house near junction with Stillwater Creek, in Section 25, Township 11 North, Range 3 West.

42

In railway cut O.-W. R. R. & N. Co. two thousand feet east of the Oakville wagon bridge over Chehalis River, in Section 1, Township 15 North, Range 5 West. Upper Eocene. Old locality 184.

43

In the bluff of Lankner Creek, Grays Harbor County, 16,000 feet up from the O.-W. R. R. & N. Co. crossing in Section 25, Township 17 North, Range 6 West. Oligocene. Old locality 185.

44

In the bluff of Lankner Creek, Grays Harbor County, 18,000 feet up from the O.-W. R. R. & N. Co. crossing in Section 25, Township 17 North, Range 6 West. Oligocene. Old locality 187.

45

In the bluff of Lankner Creek, Grays Harbor County, 25,000 feet up from the O.-W. R. R. & N. Co. crossing in Section 33, Township 17 North, Range 6 West.

46

In Grays Harbor County in O.-W. R. R. & N. Co. cut at culvert 38 east, 24,000 feet west from South Elma, in Section 7, Township 17 North, Range 6 West. Upper Miocene. Old locality 263.

47

Chicago, Milwaukee & St. Paul Railway cut 1,000 feet south from O.-W. R. R. & N. Co.'s track in Section 29, Township 17 North, Range 8 West. Lower Miocene.

49

In Section 25, Township 16 North, Range 8 West, on North River, Grays Harbor County. Lower Miocene.

50

In the banks of Wynoochee River, Grays Harbor County, 35,000 feet north of Otter Postoffice and 12,000 feet south of Refnkens' farm in Section 22, Township 19 North, Range 8 West. Upper Miocene.

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51

Five hundred feet north of locality 50 on Wynoochee River, Grays Harbor County.

52

In bluff on Wishkah River, northwestern part of Aberdeen, at a point where road to Grand Forks first reaches river after leaving Aberdeen in Section 9, Township 17 North, Range 9 West. Upper Miocene. Old locality 711.

53

Wahkiakum County in west bank of Alockaman River in Section 35, Township 10 North, Range 5 West. Lower Miocene. Old locality number 210. *Arca montereyana* abundant in nodules.

54

Four hundred feet south of locality number 53 in west bank of Alockaman River. Fossils abundant. Lower Miocene. Old locality 211.

56

In bank of creek in NW¼ of section 6, Township 9 North, Range 5 West, in Wahkiakum County. Oligocene. Old locality 213.

57

In bluff on branch of Wilson Creek in Section 36, Township 10 North, Range 6 West, Wahkiakum County. Oligocene. Old locality 214.

58

Nasel River. On Pentler's ranch, one mile west of point where wagon road crosses to south side. Oligocene.

59

On Fossil Creek near log dam in east part of Section 10 and west part of Section 11, Township 10 North, Range 6 West, in Wahkiakum County. Oligocene. Old locality 29.

60

Bluff on Chehalis River along O.-W. R. R. & N. Co. track at milepost 37, about four miles west of South Elma, in Section 11, Township 17 North, Range 7 West. Upper Miocene. Old locality 50.

61

Vance logging road at old milepost in coarse grained sandstone in Section 28, Township 18 North, Range 6 West. Upper Miocene. Old locality 51.

63

East branch of Clements logging road south of Montesano in Grays Harbor County in the Northwest quarter of Section 28, Township 17 North, Range 7 West. Lower Miocene. Old locality 54.

64

East branch of Clements logging road one-half mile east of where county wagon road crosses, in Section 27, Township 17 North, Range 7 West. Lower Miocene. Old locality 55.

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65

On east branch of Clements logging road one-half mile east of where county wagon road crosses in Section 29, Township 17 North, Range 7 West. Lower Miocene. Old locality 56.

66

On east branch of Clements logging road, one mile west of county wagon road intersection in Section 29, Township 17 North, Range 7 West. Lower Miocene. Old locality 57.

67

Bluff on Chehalis Logging Company road one mile west of Montesano in Section 6, Township 17 North, Range 7 West. Lower Miocene. Old locality 58.

68

Logging railway cut on Sylvia Creek in a conglomerate of upper Miocene age, in Section 32, Township 18 North, Range 7 West. Old locality 59.

69

Along logging railway in cut on Sylvia Creek, one-half mile north of locality 68 in conglomerates. Upper Miocene.

70

Five hundred feet north of junction of north branch of east fork of Wilson Creek in Wahkiakum County on former, in Section 36, Township 10 North, Range 6 West.

71

Two miles up middle fork of Skamokawa River from junction with main river in Wahkiakum County, Section 32, Township 10 North, Range 6 West. Oligocene. Old locality 216.

72

Wahkiakum County, on McDonald Creek, two miles above its junction with the middle fork of Wilson Creek, in Section 28, Township 10 North, Range 6 West. Oligocene. Old locality 217.

73

Station 31 on Nasel River traverse line, Pacific County, Section 6, Township 10 North, Range 8 West. Oligocene. Old locality 223.

74

Station 34, Nasel River traverse line, Pacific County, in Section 6, Township 10 North, Range 8 West. Oligocene. Old locality 224 a.

75

Station 73, Nasel River traverse line, Pacific County, in Section 25, Township 11 North, Range 9 West. Oligocene. Old locality 229.

76

Station 16, Nasel River traverse line, Pacific County, in Section 6, Township 10 North, Range 8 West. Oligocene. Old locality 231.

77

Station 22, Nasel River traverse line, Pacific County, in Section 6, Township 10 North, Range 8 West. Lower Miocene. Old locality 233.

80

1600 feet above first railroad bridge on Willapa River below Holcomb in Section 25, Township 13 North, Range 8 West. In Oligocene shales. Old locality 241.

81

One-half mile up Green Creek from Willapa River in Pacific County in Section 26, Township 13 North, Range 8 West. Oligocene. Old locality 241.

82

1200 feet above highway bridge near mouth of Green Creek. Old locality 242.

83

7050 feet up Green Creek from Willapa River, Pacific County. Oligocene. Old locality 243.

84

7750 feet up Green Creek from Willapa River, Pacific County. Oligocene. Old locality 244.

85

8250 feet up Green Creek from Willapa River, Pacific County, in Oligocene shales. Old locality 245.

86

8880 feet up Green Creek from Willapa River, Pacific County, in Oligocene shales. Old locality 246.

87

11,350 feet up Green Creek from Willapa River, Pacific County, in Oligocene shales. Old locality 247.

90

In bluff north side Chehalis River 2240 feet west of Porter station along Northern Pacific Railway track. Oligocene. Grays Harbor County in Section 21, Township 17 North, Range 5 West. Old locality 260.

92

On North River branch of Chicago, Milwaukee & St. Paul Railway grade 3000 feet north of point where wagon road goes up Vesta Creek, near Chamber's farm, Grays Harbor County, Section 25, Township 16 North, Range 8 West. Lower Miocene. Old locality 265.

93

22,000 feet up Wynoochee River from Otter Post Office, in SW¼ of Section 5, Township 18 North, Range 8 West. Upper Miocene. Old locality 270.

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94

Bluff back of Lincoln School in Hoquiam, Grays Harbor County. Poorly preserved specimens of *Scutella gabbi*. Upper Miocene.

96

28,000 feet up Falls Creek from Brooklyn in Pacific County, in Section 10, Township 15 North, Range 6 West. Old locality 281.

97

In Section 34, Township 15 North, Range 7 West, in a small creek entering North River just north of Grays Harbor-Pacific County line. Lower Miocene. Old locality 282.

98

Bluff on Willapa River, between Holcomb and the railroad bridge west of town in Section 36, Township 13 North, Range 8 West. Oligocene. Old locality 283.

99

On Wishkah River wagon road one mile north of Aberdeen in Section 4, Township 17 North, Range 9 West. Upper Miocene. Old locality 191.

100

On wagon road cut up Wishkah River road one and one-half miles below Wishkah Post Office in Section 11, Township 18 North, Range 9 West. Old locality 192.

101

One mile beyond Wishkah Post office in bank of river in Section 35, Township 19 North, Range 9 West. Upper Miocene. Old locality 193.

102

Station 837 Neah Bay-Cape Flattery traverse. About one-half mile west of Kaitlah Point in the cliffs. Oligocene.

103

At station 996, Neah Bay-Cape Flattery traverse. About one mile west of Kaitlah Point in the sea cliffs. Lower Miocene.

105

About 200 feet east of Slip Point light house, west of Clallam Bay on coast line. Lower Miocene. Old locality 92.

109 to 109

At base of cliff, Slip Point, east of Clallam Bay on coast. Lower Miocene. Old locality 92A.

111

Mouth of Maxfield Creek in southwest quarter of northwest quarter of Section 28, Township 28 North, Range 14 West. Old locality 94.

112

Southeast quarter of northwest quarter of Section 16, Township 28 North, Range 14 West. Old locality 95.

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113

Twenty feet east of line of Lot 1, Section 27, Township 28 North, Range 14 West.

114

Northeast quarter of northwest quarter of Section 27, Township 28 North, Range 14 West. Old locality 96.

115

In brown sandstone on Soleduck River bluff about center of Section 20, Township 28 North, Range 14 West. Old locality 97.

117

Station 161, Wishkah River traverse. In bank of river in Section 30, Township 20 North, Range 8 West, Grays Harbor County. Upper Miocene. Old locality 2032.

118

Middle fork of Wishkah River 300 feet south of locality 117 in bank of river. Upper Miocene. Old locality 2033.

119

Middle fork of Wishkah River 1200 feet south of locality 117 in bank of river. Upper Miocene. Old locality 2033A.

120

Middle fork of Wishkah River 100 feet south of locality 117 in bank of river. Upper Miocene. Old locality 2034.

121

Middle branch of Wishkah River in east central part of Section 31, Township 20 North, Range 8 West. Upper Miocene. Old locality 2035.

122

Middle branch of Wishkah River, 800 feet west of locality 121. Upper Miocene. Old locality 2036.

123

Middle branch of Wishkah River in south central part of Section 36, Township 20 North, Range 9 West. Upper Miocene. Old locality 2037.

124

Middle branch of Wishkah River 1000 feet southwest of locality 123. Upper Miocene. Old locality 2038.

125

Middle branch of Wishkah River in southwest quarter of Section 1, Township 19 North, Range 9 West. Upper Miocene. Old locality 2039.

126

One and one-half miles north of Hoquiam on road to Copalis in a cut on west side of road, in Section 34, Township 18 North, Range 10 West. Upper Miocene. Old locality 901.

128

At survey stake 388 on North River branch of Chicago, Milwaukee & St. Paul Railway in Grays Harbor County in Section 29, Township 17 North, Range 8 West. Lower Miocene. Old locality 903.

129

In south bank of south fork of Stillaguamish River in Section 11, Township 30 North, Range 6 East, Snohomish County. Oligocene.

130

On west bank of Wilson Creek, Pacific County, one mile west of Willapa Post Office, in Section 21, Township 14 North, Range 8 West. Oligocene.

131

Logging railroad cut one mile west of Montesano, Grays Harbor County, in Section 1, Township 17 North, Range 8 West. Lower Miocene.

132

North River branch of Chicago, Milwaukee & St. Paul Railway, 300 feet south and up hill from culvert 38 of O.-W. R. R. & N. Co. track in Section 29, Township 17 North, Range 8 West. Lower Miocene. Old locality 1000.

133

North River branch of Chicago, Milwaukee & St. Paul Railway, 200 feet to the southwest from locality 132.

135

Railway cut on North River branch of Chicago, Milwaukee & St. Paul Railway in the northeast quarter of the northwest quarter of Section 29, Township 17 North, Range 8 West. Lower Miocene. Old locality 1008.

136

Railroad cut 300 feet west of locality 135. Lower Miocene. Old locality 1009.

137

Bluff in wagon road along east side of Wynoochee River one mile south of Bitter Creek in Section 35, Township 18 North, Range 8 West. Lower Miocene.

138

In bank of Wynoochee River along wagon road 600 feet north of station 137. Lower Miocene.

140

Cut in south side of "Think of Me" hill in East Aberdeen, Grays Harbor County. Upper Miocene.

141

Northern Pacific Railway cut 3000 feet east of locality 140, Aberdeen.

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142

Northern Pacific Railway cut 270 feet east of locality 141, Aberdeen.

144

Stratum 20 feet stratigraphically above that at locality 142 in the Northern Pacific Railway cut east of Aberdeen.

145

In cut at Aberdeen, Grays Harbor County, at corner Summit and Chehalis streets.

146

Survey stake 110 on Chicago, Milwaukee & St. Paul Railway at Cosmopolis, Grays Harbor County, in section 23, Township 17 North, Range 9 West. Upper Miocene.

147

Railroad cut on Chicago, Milwaukee & St. Paul Railway track 400 feet east of locality 146.

148

Ocean bluff one mile north of Point Grenville in Section 13, Township 21 North, Range 13 West. Upper Miocene.

151

Log dam number 35 on the west fork of Wishkah River in Section 35, Township 20 North, Range 9 West. Upper Miocene. Old locality number 100,006.

152

One hundred feet south of locality 151 in canyon of West branch of Wishkah River.

154

North side of Restoration Point, Kitsap County. Oligocene.

155

Small creek emptying into Coal Creek, King County in Section 23, Township 24 North, Range 5 East. Oligocene.

156

Southeast quarter, Section 13, Township 24 North, Range 5 East, one mile west of Lake Sammamish, King County. Oligocene.

157

One mile east of locality 156 in Section 14, Township 24 North, Range 5 East. Lower Miocene.

158

One-fourth mile north of Woodman's station on shore of Port Discovery Bay in Section 5, Township 29 North, Range 1 West. Oligocene.

159

Three hundred feet north of locality 158 on east shore of Port Discovery Bay.

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160

Bluff at Porter Station in N. P. Railroad cut in Section 22, Township 17 North, Range 4 West. Oligocene.

161

In wagon road cut one-half mile east of Porter in Section 27, Township 17 North, Range 4 West. Oligocene.

162

On western shore, Port Townsend Bay, in Section 36, Township 30 North, Range 1 West. Oligocene.

163

On western shore Port Townsend Bay in Section 36, Township 30 North, Range 1 West. Oligocene.

164

At Restoration Point, Kitsap County.

165

Oak Bay on western shore just south of ship canal spit, in Section 7, Township 29 North, Range 1 East. Oligocene.

166

Six hundred feet west of Porter station in Northern Pacific Railway cut, Section 22, Township 17 North, Range 5 West. Oligocene.

167

Wagon road cut on Wilson Creek, Pacific County, in Section 21, Township 14 North, Range 8 West. Oligocene.

168

Old embankment along Willapa River at trestle in Section 27, Township 14 North, Range 8 West, one-half mile south of Willapa Post Office, Pacific County. Oligocene.

169

Oakville quarry, in sandstone overlying basalt, one mile west of Oakville, Grays Harbor County, on Northern Pacific track. Section 19, Township 16 North, Range 4 West. Oligocene.

170

Half Moon Creek, Pacific County, in Section 34, Township 13 North, Range 7 West.

172

Street cut Columbia City, Seattle, at 50th Avenue South, and one and one-half blocks south of Ferdinand Street. Oligocene.

173

Street grade Columbia City, Seattle, corner 42nd Street and Juneau Street. Oligocene.

176

Bank of small stream entering Satsop River from west, in Section 23, Township 18 North, Range 7 West. Upper Miocene.

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174

Bank of small stream entering Satsop River from west, in Section 23, Township 18 North, Range 7 West. Upper Miocene.

175

Bank of small stream entering Satsop River from west, in Section 23, Township 18 North, Range 7 West. Upper Miocene.

177

Ocean cliff south from Hoh River in Section 32, Township 26 North, Range 13 West. Probably upper Miocene. Jefferson County.

178

Bluff along south shore of Strait of Juan de Fuca in Clallam County, one and one-half miles west of Twin Post Office, Section 22, Township 31 North, Range 10 West. Oligocene.

179

1000 feet west of mouth of West Twin River in Section 22, Township 31 North, Range 10 West. Oligocene.

180

Oak Bay, Jefferson County, in cliff in north half of Section 18, Township 29 North, Range 1 East. Oligocene.

181

Cape Elizabeth, Grays Harbor County, Section 34, Township 21 North, Range 13 West. Upper Miocene.

182

Six hundred feet south of Keyhole at Cape Elizabeth, Grays Harbor County. Upper Miocene.

185

One and one-fourth miles north of Point Grenville, Grays Harbor County, Washington, in Section 25, Township 21 North, Range 13 West. Upper Miocene.

187

Cut along street car track in north end of Columbia City, Seattle. Oligocene.

188

King coal mine north of Issaquah, King County, in Section 22, Township 24 North, Range 7 West. Lower Miocene.

189

Conglomerate bank along Silvia Creek, Grays Harbor County, in Section 32, Township 18 North, Range 7 West. Upper Miocene.

192

Columbia City, Seattle, from hill six blocks west of City Hall. Oligocene.

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193

Bluff north side of mouth of Raft River, Grays Harbor County, Section 21, Township 23 North, Range 13 West. Upper Miocene.

194

At culvert 38, in bluff along O.-W. R. R. & N. Co. track, 14 miles west of South Montesano, Grays Harbor County. Upper Miocene.

195

Section 25, Township 10 North, Range 9 West. Oligocene. Pacific County.

196

Two miles west of Winlock, Lewis County, in bank of a creek in Section 20, Township 12 North, Range 2 West. Oligocene.

197

Three-fourths mile north of Point Grenville, Grays Harbor County, Washington. Upper Miocene.

199

Cut in left hand branch of Clement's logging road three-fourths mile west of wagon road intersection in Section 20, Township 17 North, Range 7 West.

200

Cut in Northern Pacific Railway one mile east of railroad bridge over Wishkah River at Aberdeen, Grays Harbor County. Upper Miocene. Old locality number 412.

201

One and one-half miles north of Point Grenville in cliffs along ocean.

202

One and three-fourths miles north of Point Grenville in cliffs along ocean.

203

Five hundred feet west of railway station at Porter in cut of Northern Pacific Railway, Grays Harbor County. Former locality 406.

204

Cliff along shore line in northwest quarter, Section 15, Township 22 North, Range 13 West. Upper Miocene. North of Cape Elizabeth.

205

East center portion of Section 9, Township 22 North, Range 13 West, north of Cape Elizabeth. Upper Miocene.

206

Exposure on Germany Creek, Cowlitz County, in Section 12, Township 9 North, Range 4 West. Oligocene.

207

Cut back of Olympic Foundry, South Seattle, King County, in a bluff along east side of Duwamish Valley. Oligocene. North half, Section 20, Township 24 North, Range 4 East.

209

Bluff in main branch of Wishkah River in Section 27, Township 19 North, Range 9 West. Upper Miocene.

215

In Section 29, Township 17 North, Range 8 West, in cut on North River branch of Chicago, Milwaukee & St. Paul Railway.

218

Denny Renton mine Number 2. Second level, in Section 3, Township 22 North, Range 7 East. In brackish water phase of Eocene at Taylor.

219

Denny Renton Coal mine Number 6, at Taylor, King County, in Section 3, Township 22 North, Range 7 East. In brackish water phase of Eocene.

220

One-half mile east of Duwamish in a small creek at a point where a well has been sunk, in northwest quarter, Section 11, Township 23 North, Range 4 East. Eocene brackish water strata.

221

Fossil ledge above Franklin wagon bridge in Green River in Section 10, Township 21 North, Range 7 East. Brackish water Eocene.

222

Cut in Northern Pacific Railway track, one mile south of Duwamish Station, King County, in Section 14, Township 23 North, Range 4 East. Brackish water Eocene.

224

Section 5, Township 18 North, Range 6 West, in logging road cut, Chehalis County. Upper Miocene, coarse grained, cross bedded sandstone.

226

One mile up Olequa Creek above Winlock in Lewis County. Section 29, Township 12 North, Range 2 West. Eocene.

228

Railroad cuts one mile north of Cathcart Station along Northern Pacific Railway. In Section 21, Township 28 North, Range 9 East. Oligocene.

229

Cuts along road and in Wynoochee River banks one mile south of junction with Bitter Creek in Section 35, Township 18 North, Range 8 West. Lower Miocene. Collection of August, 1913. Old locality Number 102.

230

A cut in the North River branch of Chicago, Milwaukee & St. Paul Railway about two miles beyond its junction with the O.-W. R. R. & N. Co. Lower Miocene. Grays Harbor County. Collected July, 1913.

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231

Olequa Creek about three-fourths of a mile north of Vader, just south of big bend in creek. A small band of fossils. In Section 29, Township 11 North, Range 2 West. Marine Eocene.

232

West bank and cliff of Cowlitz River, one thousand feet below bend and below locality 233, in Section 11 North, Range 2 West. Marine Eocene.

233

West bank and cliff of Cowlitz River at bend in Section 28, Township 11 North, Range 2 West. Fossils in an excellent state of preservation. Marine Eocene.

234

A narrow band of strata in Olequa Creek about three-fourths of a mile north of Vader just south of big bend in creek. About eight feet stratigraphically above locality 231. In Section 29, Township 11 North, Range 2 West. Marine Eocene.

235

West bank of the mill pond of the O'Connell Lumber Company up Olequa Creek one-half mile above depot at Winlock in Section 28, Township 12 North, Range 2 West. Oligocene. Occurs in residual patches.

236

Stillwater Creek, Lewis County, 2200 feet above its junction with Olequa Creek in Section 30, Township 11 North, Range 2 West. Eocene.

237

Olequa Creek one-fourth mile above Vader Station in east bank of creek just north of point where small creek enters Olequa Creek from the east. In Section 29, Township 11 North, Range 2 West. Eocene.

238

On Olequa Creek three-fourths of a mile north of Vader Station in bend just north of anticlinal axis, about five hundred feet south of locality 231. Section 29, Township 11 North, Range 2 West. Eocene.

239

Northeast quarter of Section 25, Township 11 North, Range 2 West, on east side of Cowlitz River three-fourths of a mile above ferry on Mr. Greece's farm. Oligocene.

240

East bank of Olequa Creek about one-third mile below its junction with Stillwater Creek and just below Northern Pacific Railroad bridge. In Section 32, Township 11 North, Range 2 West. Eocene.

DNR-00005304

241

Bank of Stillwater Creek about one and one-half miles above junction with Olequa Creek in Section 30, Township 11 North, Range 2 West. Marine Eocene.

242

Between localities 233 and 232 in bank of Cowlitz River in Section 28, Township 11 North, Range 2 West. Eocene.

243

Coal Creek, Cowlitz County, at the main camp of the Inman Polson Logging Company on the north bank of the creek immediately back of the Y. M. C. A. shack. There is a 10-foot bank composed in large part of massed and broken shells, in Section 27, Township 9 North, Range 3 West. Eocene.

244

Bank of Coal Creek, Cowlitz County, about one-half mile below Inman Polson Company's store. Oysters. Section 11, Township 8 North, Range 3 West, near center of section. Eocene.

245

Bank of Coal Creek, Cowlitz County, about one-fourth mile down stream from Inman Polson Company's store. An oyster bed about twelve inches thick. In northeast corner of Section 11, Township 8 North, Range 3 West. Eocene.

246

East bank of Coal Creek about one-fourth mile below school house in a small sandy ledge at foot of cliff. In Section 35, Township 9 North, Range 3 West, near center of section. Eocene.

247

Coal Creek, Cowlitz County, about one and one-half miles below Inman Polson Company's store at the old dam in the extreme southwest quarter of Section 11, Township 8 North, Range 3 West. Eocene.

248

Coal Creek, Cowlitz County, about one and one-fourth miles down stream below Inman Polson Logging Company's store on the east bank in the canyon. In southeast quarter of southeast quarter of Section 10, Township 8 North, Range 3 West.

249

Coal Creek, Cowlitz County, about one and one-fourth miles down stream below Inman Polson Logging Company's store on the west bank of the creek in the canyon and opposite locality 248. Mostly oysters. In Section 10, Township 8 North, Range 3 West. Eocene.

250

Alockaman River in Wahkiakum County about one-half mile above the forks on the east fork. A small ledge at the water's edge at the foot of a 30-foot cliff. Near boundary line between Sections 25 and 24, Township 10 North, Range 5 West. Lower Miocene.

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251

Alockaman River in Wahkiakum County near the center of the southeast quarter of Section 26, Township 10 North, Range 5 West, on the Clinton Olmstead homestead. Oligocene.

255

In railroad cut on the O.-W. R. & N. Co. one-fourth mile north of Lincoln Creek Station in Section 26, Township 15 North, Range 3 West. Oligocene.

256

In railroad cut on O.-W. R. R. & N. Co. one mile north of Lincoln Creek Station in Section 27, Township 15 North, Range 3 West. Oligocene.

257

North bank of Columbia River, two hundred feet west of the mouth of Sisson Creek in Wahkiakum County in Section 6, Township 9 North, Range 8 West. Oligocene.

258

One-half mile west of Twin Postoffice, Clallam County, in sea cliff in Section 27, Township 31 North, Range 10 West. Oligocene.

259

Two miles west of Gettysburg, Clallam County, in sea cliff in northwest quarter, Section 29, Township 31 North, Range 9 West. Oligocene.

261

Cliff on north shore of Columbia River about one-half mile east of Knappton, Pacific County. Fossils occur in nodules. In Section 9, Township 9 North, Range 9 West. Oligocene.

262

One and one-eighth miles west of Lincoln Creek Station in bluff along O.-W. R. R. & N. Co. in Lewis County. In Section 26, Township 14 North, Range 3 West. Oligocene.

263

Bluffs along bend in Cowlitz River in Section 28, Township 11 North, Range 2 West. Marine upper Eocene.

264

Bluff on south side of Bear River, Pacific County, on line between Sections 20 and 21, Township 10 North, Range 10 West. Oligocene.

265

Bluff on east side of Shoalwater Bay, Pacific County in Section 29, Township 11 North, Range 10 West. Oligocene.

267

East shore of Port Discovery Bay in Jefferson County in Section 5, Township 29 North, Range 1 West. Oligocene.

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268

South shore Strait of Juan de Fuca in Clallam County, about three miles west of Piller Point, in Section 32, Township 31 North, Range 12 West. Lower Miocene.

269

Shore of Strait of Juan de Fuca in Clallam County one mile and a half west of the coal mine in Section 23, Township 32 North, Range 12 West. Lower Miocene.

270

Cliff south shore of Strait of Juan de Fuca in Clallam County in Section 21, Township 32 North, Range 12 West. Lower Miocene.

271

Cliff south shore of Strait of Juan de Fuca in Clallam County in Section 22, Township 31 North, Range 9 West, about one thousand feet west of locality 258. Lower Miocene.

272

Cliff south shore of Strait of Juan de Fuca in Clallam County in Section 19, Township 31 North, Range 9 West. About one mile west of locality 259. Lower Miocene.

273

Cliff south shore of Strait of Juan de Fuca in Clallam County, in Section 24, Township 31 North, Range 10 West, about one-half mile east of east fork of Twin River and just east of rocky bluff. Lower Miocene.

274

Cliff south shore of Strait of Juan de Fuca in Clallam County in Section 21, Township 31 North, Range 10 West. Lower Miocene.

276

Old Washington Geological Survey collection of 1902 from Cowlitz County, in Section 11, Township 9 North, Range 2 West. Eocene. Former locality 3.

277

Old Washington Geological Survey collection of 1902 from Cowlitz County in Section 25, Township 9 North, Range 2 West. The Pecten locality east of Castle Rock. Eocene. Former locality 2.

278

Old Washington Geological Survey collection of 1902 from Cowlitz County in Section 13, Township 9 North, Range 2 West. Eocene. Former locality 4.

279

Old Washington Geological Survey collection of 1902 from Cowlitz County on Arkansas Creek, three miles west of Castle Rock. Eocene. Former locality 5. Pectens are common.

280

Old Washington Geological Survey collection of 1902. From Lewis County in Chehalis hill one-fourth mile southeast of hotel. Eocene. Former locality 6.

281

Old Washington Geological Survey collection of 1902 in Lewis County on Olequa Creek, one mile up creek from Winlock. Former locality 7.

282

Old Washington Geological Survey collection of 1902 in Cowlitz County twelve miles west of Kelso. Eocene. Former locality 8.

283

Old Washington Geological Survey collection of 1902 in Cowlitz County twelve miles west of Kelso. Eocene. Former locality 9.

285

One mile west of Oakville, Grays Harbor County, in Section 19, Township 16 North, Range 4 West. Oligocene.

288

From falls on Scantogrese Creek near Castle Rock in S. E. quarter, Section 18, Township 9 North, Range 2 West. Eocene.

289

Near an old coal prospect in Section 31, Township 10 North, Range 2 West. Eocene.

290

Near Pecten locality in Section 24, Township 9 North, Range 2 West. Eocene.

291

Near Winlock, Lewis County, in Section 28, on Olequa Creek in bluff near junction of west branch of Olequa Creek west from millpond. Oligocene.

292

West branch of Olequa Creek one-half mile above junction of main creek. Oligocene.

293

North end of big slide on N. P. Railway cut one-half mile north of Tenino in Thurston County in Section 17, Township 16 North, Range 1 West. Oligocene.

294

McClarity ranch on south bank of Stillwater Creek one mile west of Vader in Section 30, Township 11 North, Range 2 West. Eocene.

295

One and one-half miles north of Vader in Lewis County in bed of Olequa Creek at milepost 73 on Northern Pacific Railway in Section 20, Township 11 North, Range 2 West. Eocene.

296

On Booth Ranch two and one-quarter miles up Stillwater Creek from junction with Olequa Creek in Section 24, Township 11 North, Range 3 West. Eocene.

297

On Olequa Creek one-eighth mile north of railway station at Vader in Section 29, Township 11 North, Range 2 West. Eocene.

298

Three-fourths mile west of Vader on Stillwater Creek in Section 30, Township 11 North, Range 2 West. Eocene.

299

Rock bluff in N. P. Railway cut 2850 feet south of mile post 76 and three-fourths mile north of Olequa railway station in Section 4, Township 10 North, Range 2 West. Eocene.

300

Banks of Olequa Creek at the old Cantwell place north of Vader in Section 20, Township 11 North, Range 2 West. Eocene.

304

The west end of rock island west of Point Glover quarry near entrance to Bremerton Inlet in Section 8, Township 24 North, Range 2 East. Oligocene.

305

At Bean Point south end of Bainbridge Island in Section 14, Township 24 North, Range 2 East. Middle Oligocene.

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OF THE

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Power Reports.

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Water-Supply Paper No. 412: Surface Water Supply of the United States, North Pacific Coast, 1915. In preparation.

Qualitative Report.

(Principally in cooperation with State Board of Health.)

Water-Supply Paper No. 339: Quality of Surface Waters of Washington.

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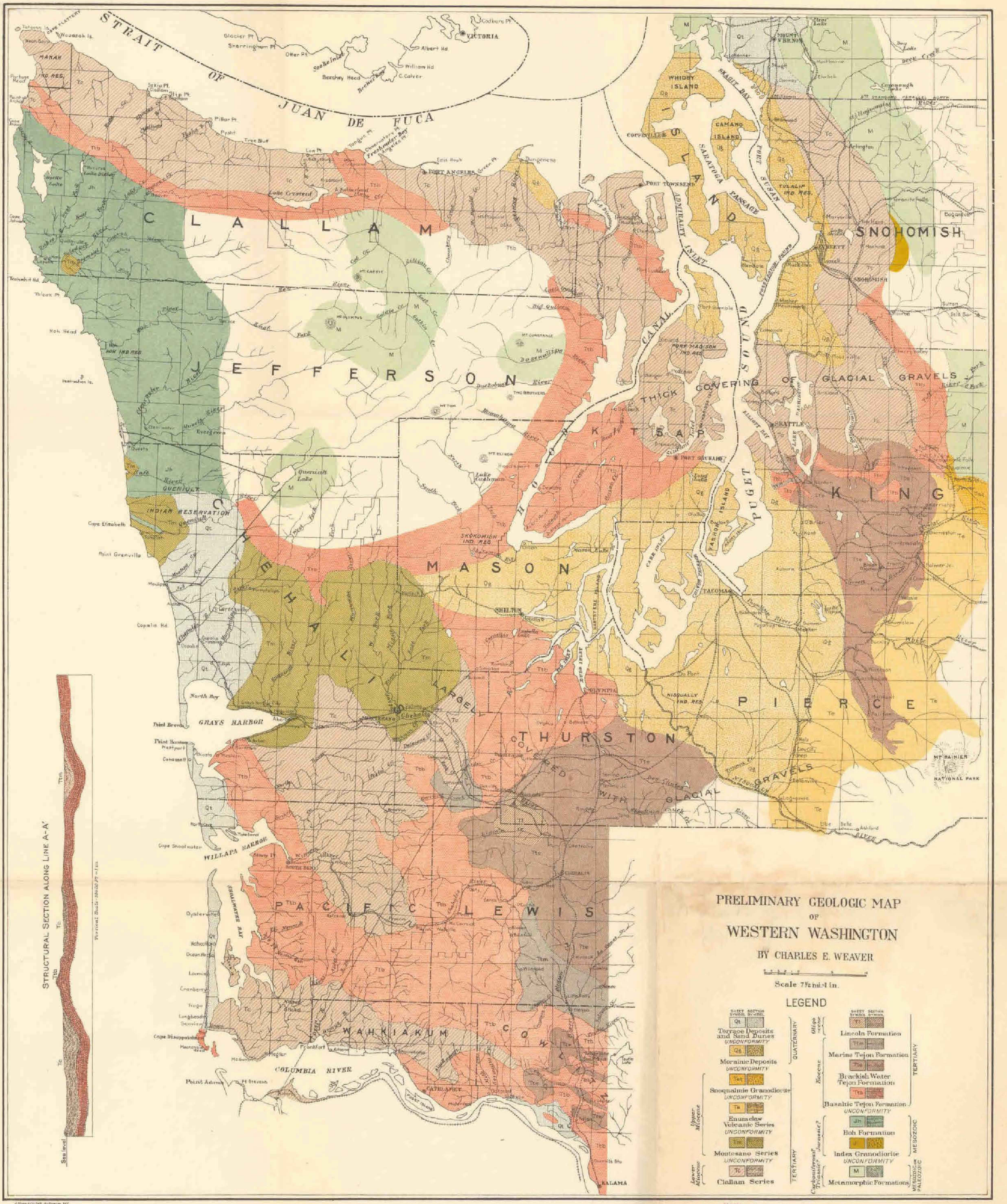

NOTE. LATER FIELD STUDIES INDICATE THE FOLLOWING CHANGES IN CLASSIFICATION: UPPER THIRD OF AREA MAPPED AS CLALLAM FORMATION IS LOWER MIOCENE; LOWER TWO-THIRDS OF AREA TOGETHER WITH THE LINCOLN FORMATION IS OLIGOCENE IN AGE.

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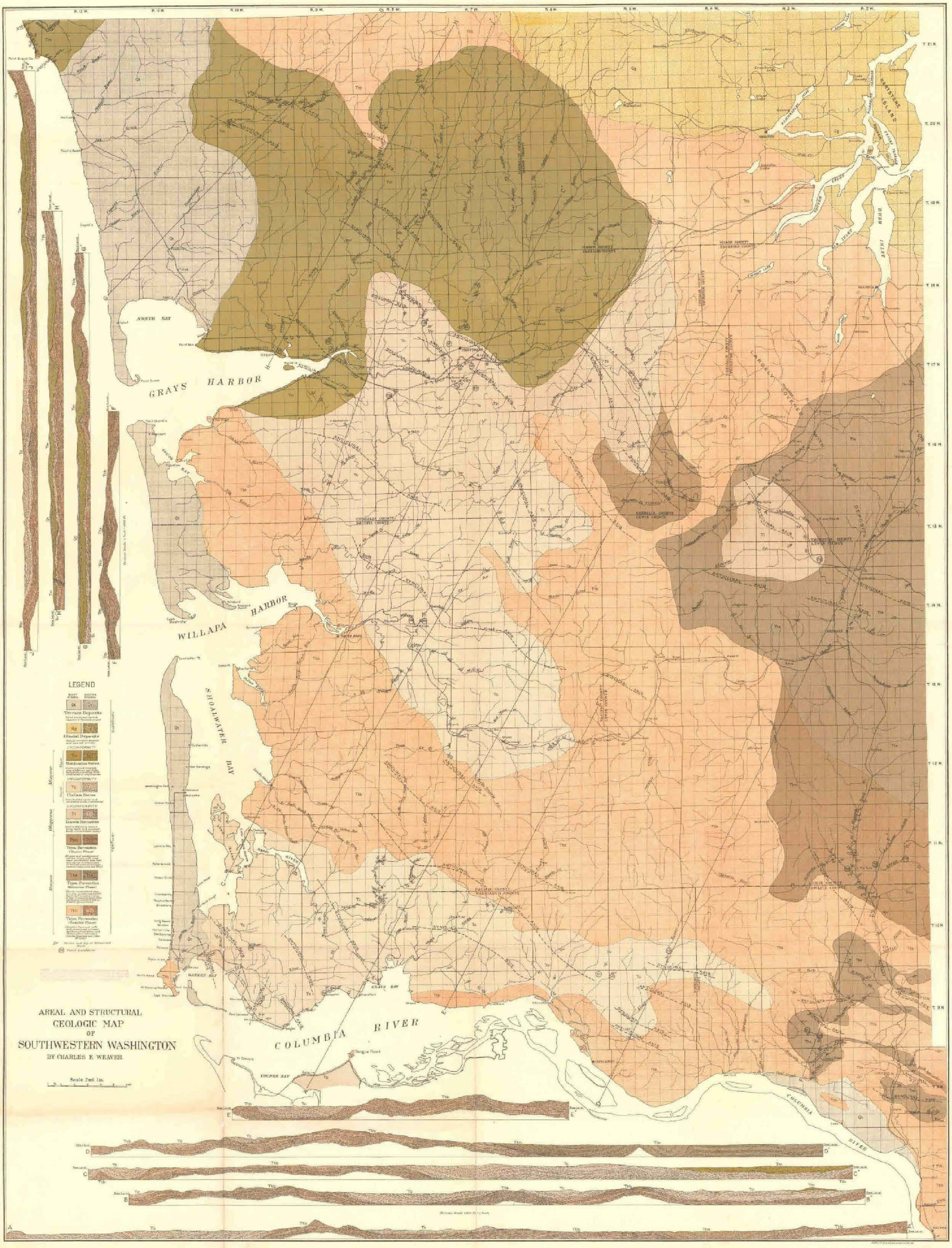

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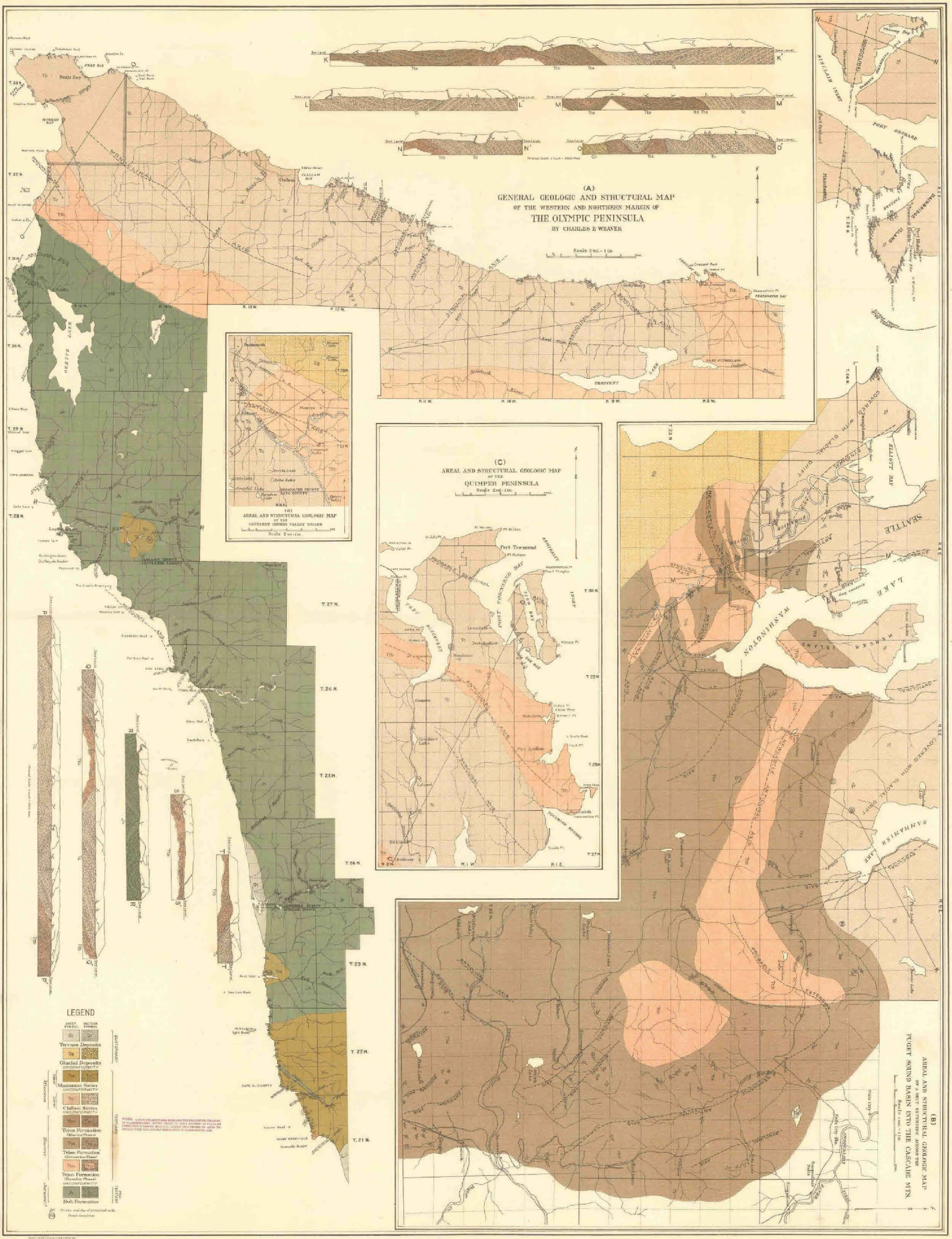

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